THE ENGINEER

A Seven-Day Journal

The Budget

When presenting his Budget to the House of Commons on Tuesday last, the Chancellor of the Exchequer estimated that by the end of the financial year expenditure would be about £4070 millions and total revenue some £4440 millions. The expenditure was about £120 millions less than the estimates, and one of the reasons for this was the fact that spending on defence had been less than expected, although the Ministry of Supply expenditure exceeded that estimated by about £50 million. Over the year the deficit on the balance of payments was over £400 million more than was bargained for. One of the big contributory causes of this deficit was the rise in imports, which, compared with 1950, had increased in volume by about £300 million, but because of higher prices the total increase in this bill was some £1100 million. The resultant balance of payments deficit was £516 million, as compared with an overall surplus of £238 million the year before—a swing of no less than £750 million. In speaking of the measures being adopted to halt the drain on our reserves, the Chancellor pointed out that even in 1951 the volume of imports was no more than 90 to 95 per cent of that in 1938. This was despite a population increase of 6 per cent and an industrial production increase—which was mostly based upon imported materials—of more than 40 per cent. Although there was not much margin, it had been decided to reduce the 1952 import programme by again cutting purchases. As part of this plan the open general licences for a further list of selected goods is to be withdrawn. The various import cuts which have been made, which will amount to another £100 million, will reduce the value of imports in 1952 to about £3150 million if prices remain on about the same level as at the beginning of the year. This is a reduction of about 10 per cent on imports for 1951 or of over 15 per cent on the annual rate for the second half of that year.

The Professional Engineers' Appointments Bureau

The annual report of the Professional Engineers' Appointments Bureau, which was issued last week, records considerable progress during 1951. The increased number of placings, together with the highest total for appointment fees in any year since the Bureau was established, is a measure of the success with which it has been possible to satisfy the demands of both engineers and employers. Offers of employment last year far exceeded the number of actual appointments made owing to the existing abnormal demand for engineers with specialised experience. The nominations to vacancies which the Bureau made last year were higher than in previous years, and the number of inquiries from employers was well maintained. The total vacancies were 1070, of which 314 were for civil engineers, 503 for mechanical engineers and 253 for electrical engineers. Overseas vacancies were approximately 30 per cent of the total notified. The total number of nominations made by the Bureau was 7276, which included 2050 civil engineers, 3444 mechanical engineers and 1782 electrical engineers. An interesting point in the report is that about 10 per cent of those placed by the Bureau were over fifty years of age. Enrolments at the end of last year totalled 1679, compared with 1947 in 1950 and 1981 in 1949. Mr. J. Muil continues to act as Registrar of the Bureau, and wishes it to be known that he is prepared to receive applications for registration for employment from members of the Institution of Civil Engineers, the Institution of Mechanical Engineers and the Institution of Electrical Engineers or from persons whose engineering qualifications for election to one of those bodies have been approved. The address of the Bureau is 9, Victoria Street, London, S.W.1.

National Coal Board's Awards to Inventors

The National Coal Board has announced that it will make cash awards to its employees for technical inventions which can be usefully applied within its mining or ancillary activities. Awards panels which are being set up in each of the Board's nine divisions will have power to recommend payment of up to £100 for any one invention, and a National Tribunal, under independent control, will deal with inventions considered to be worth more than £100. Inventors will also be free to appeal from a divisional panel to this Tribunal, which can recommend awards up to any amount. The object of the scheme is to encourage the National Coal Board's employees to be inventive and to bring forward their ideas so that they can be developed quickly and made available in the best interests of the coal industry as a whole. The Board says that, to qualify for an award, the inventor will have to show that his idea is original, workable and useful, though it need not necessarily be patentable. An inventor must also be willing to assign to the Board the rights in his invention where they do not automatically belong to the Board under the Common Law or his contract of service. Those normally engaged in research or the development of new machines or processes will not be eligible for awards if in making an invention they have done no more than carry out their duties efficiently and successfully. The scheme does not cover ideas for methods of working or management. Sir Ernest Gowers is the independent chairman of the National Tribunal, the other members of which are Professor D. M. Newitt, Sir William Stanier, Sir Andrew Bryan, Mr. H. J. Crofts and Mr. R. M. Marson.

A Film on Harbour Construction in West Africa

We were recently invited to see a film entitled "Takoradi," which depicts the considerable work of extending the harbour of Takoradi, on the Gold Coast. The project has been under construction since 1949 and is due to be completed next year; an account of the various extensions involved was given in our issue of February 15th last, to which reference should be made for a more detailed description. The film is in colour and runs for 45 minutes. It gives a good idea of the problems of carrying out a large-scale constructional work in a tropical environment such as the Gold Coast. The description of the harbour works is clear and both sufficiently simple to be followed by most laymen, and sufficiently detailed to hold the attention of most engineers, provided they are not looking for explanations of the finer points of design or construction. Emplacement of the in-situ concrete work of the medium-to-shallow water quays of the timber depot is shown, as is the building of the deep water quay with precast blocks. The supply of materials and the use of a local labour force are both prominent subjects in the film. Natives are shown operating the constructional plant at the site, and at the aggregate quarry. A hill in the harbour area—Cox's Fort Hill—containing 1½ million cubic yards of material, has been removed to provide space for marshalling yards, and the spoil used for reclamation. This work is shown being carried out entirely by mechanical means. By contrast, the 30ft of overburden at the quarry was removed by hand by a sub-contractor, and native labourers are shown at work with shovels and barrows. "Takoradi" was made by the Orion Picture Corporation for Taylor Woodrow (West Africa), Ltd., the contractors at Takoradi harbour; the consulting engineers for the project are Messrs. Rendel Palmer and Tritton.

The Late Mr. W. H. Pilmour

It is with regret that we record the sudden death of Mr. W. H. Pilmour, the managing director and Secretary of Parsons Marine Steam Turbine Company, Ltd., which occurred in his office on Friday, March 7th. Mr. Pilmour, who was seventy-five years of age, joined the company fifty-four years ago and two years later was appointed secretary. In those days the "Turbinia" had just created history by demonstrating the possibilities of Parsons turbine machinery and Mr. Pilmour was closely associated with Sir Charles Parsons during the early trials and succeeding developments. He was elected a director of the company in 1930 and three years later he became deputy managing director and then, in 1936, he was appointed managing director, a post which he continued to fill, together with that of secretary, up to the day of his death. In 1937 Mr. Pilmour, who was a Fellow of the Chartered Institute of Secretaries, was elected an Associate of the Institution of Naval Architects and a Companion of the Institute of Marine Engineers, and for a number of years served the North-East Coast Institution of Engineers and Shipbuilders in the capacity of honorary treasurer.

Report on the Monopolies and Restrictive Practices Act

The Board of Trade has issued its third annual report on the working of the Monopolies and Restrictive Prices (Inquiry and Control) Act, 1948, for the calendar year 1951. In notes on the work of the Monopolies and Restrictive Practices Commission it is stated that the main task during the year under review was to complete the inquiries set on foot by the first set of six references made by the Board of Trade in 1949. Early in the year the report on the supply of cast iron rain-water goods was signed and laid before Parliament, and that on the supply of electric lamps was signed in August, 1951, and presented. At the time of the report the Commission had before it seven references of subjects for investigation. These seven references—the first three of which were referred to the Commission at its inception in March, 1949—included the following subjects: the supply of insulated electric wires and cables, the supply of machinery for the manufacture of matches, the supply of matches and export of matches from the United Kingdom, the supply of insulin, the supply of various semi-manufactures of copper and copper-based alloys and exports of such products, the application of the process of printing to woven fabrics, and the supply of various descriptions of imported hardwood and softwood timber and plywood. Many items are listed in the section of the report surveying the suggestions and requests made to the Board of Trade for reference to the Commission. It is pointed out that a majority of these suggestions and requests have come from business people who consider their competitive position impaired by the arrangements which they suggest for investigation. Amongst the subjects suggested for reference for the first time in 1951 are domestic boilers, leather, steam boilers, steelwork erection and printing blocks.

Cross-Channel Steamer "Normannia"

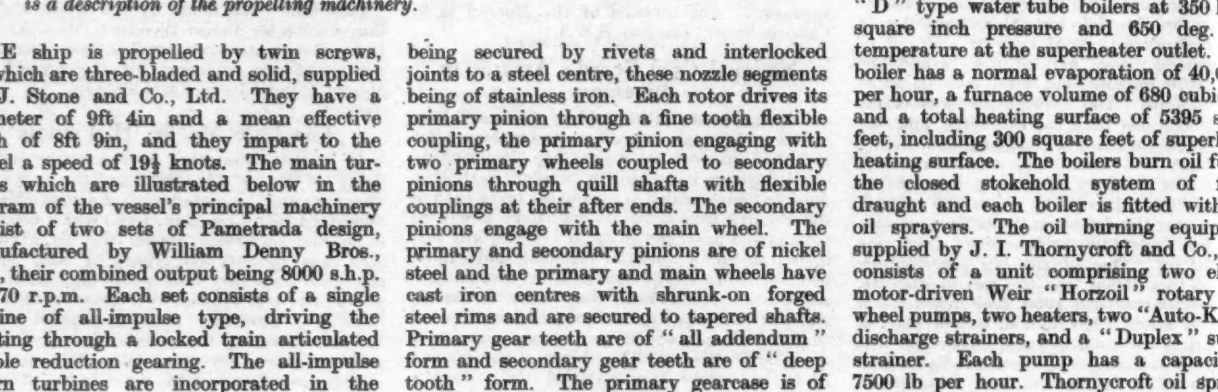
By G. W. TRIPP, O.B.E., F.C.G.I., M.I.C.E.

No. II—(*Concluded from page 332, March 7th*)

The cross-channel steamer "Normannia," which entered the Southampton/Havre service of the British Railways on March 3rd, replaces the original "Normannia," lost at Dunkirk in May, 1940. The ship has a length between perpendiculars of 291ft by 48ft breadth moulded, by 25ft 6in depth moulded, and a tonnage of 3543 gross. Two sets of double-reduction geared turbines of 8000 total s.h.p. give the ship a speed of 19½ knots. Last week we described the accommodation and this week there is a description of the propelling machinery.

THE ship is propelled by twin screws, which are three-bladed and solid, supplied by J. Stone and Co., Ltd. They have a diameter of 9ft 4in and a mean effective pitch of 8ft 9in, and they impart to the vessel a speed of 19½ knots. The main turbines which are illustrated below in the diagram of the vessel's principal machinery consist of two sets of Pametrada design, manufactured by William Denny Bros., Ltd., their combined output being 8000 s.h.p. at 270 r.p.m. Each set consists of a single turbine of all-impulse type, driving the shafting through a locked train articulated double reduction gearing. The all-impulse astern turbines are incorporated in the ahead casings and impart 85 per cent of the ahead power. The propellers turn outboard when running ahead. The nozzles and diaphragms of each turbine, ahead and astern, are carried in a single pressure casing of cast steel supported within an outer fabricated shell and so arranged to accommodate differential expansion. The space between the outer shell and pressure casing is in communication with the steam space of the condenser, thus giving uniform temperature conditions all round the pressure casing, and obviating the necessity for insulation of the outer shell. The after end of the outer shell is rigidly bolted to the gearcase, the forward end being carried on a suitable seating, while the condenser is bolted to the lower half of the outer shell. The turbine rotors are machined from single forgings, and the first critical speed is 30 per cent above maximum running speed. Blading and shrouding are of stainless iron. Each nozzle passage is machined from a separate nozzle segment, the segments being secured by rivets and interlocked joints to a steel centre, these nozzle segments being of stainless iron. Each rotor drives its primary pinion through a fine tooth flexible coupling, the primary pinion engaging with two primary wheels coupled to secondary pinions through quill shafts with flexible couplings at their after ends. The secondary pinions engage with the main wheel. The primary and secondary pinions are of nickel steel and the primary and main wheels have cast iron centres with shrunk-on forged steel rims and are secured to tapered shafts. Primary gear teeth are of "all addendum" form and secondary gear teeth are of "deep tooth" form. The primary gearcase is of cast iron, and the secondary of fabricated steel plate. The thrust blocks, of Michell line contact type, are incorporated in the gearcases. The shafting is supported in Cooper split roller bearings, and the tail-shafts, which are without liners, run in oil-filled stern tubes and have normal packed glands at their inboard ends and Newark patent oil glands at the outboard ends. The stern tube bushes are of brass lined with white metal. The main engines are controlled by Cockburn super-balanced manœuvring valves, with cast steel bodies, stainless steel spindles and nickel alloy valves and seats. There is separate hand wheel control for ahead and astern valves, a leak-off and drain valve being incorporated in each astern valve. Emergency shut-off valves are fitted between boilers and manœuvring valves, and close automatically in the event of low vacuum conditions. Cockburn self-closing stop valves are installed between the ahead manœuvring valves and turbines, arranged to close automatically in the event of overspeed undue axial clearance, or loss of lubricating oil pressure. These valves work in conjunction with Aspinall governors at the turbines. This arrangement permits astern steam to be available to bring the turbines rapidly to rest in the event of low lubricating oil pressure. Electric turning gear is provided for the main engines.

Steam for the main and auxiliary machinery is supplied by two Foster-Wheeler "D" type water tube boilers at 350 lb per square inch pressure and 650 deg. Fah. temperature at the superheater outlet. Each boiler has a normal evaporation of 40,000 lb per hour, a furnace volume of 680 cubic feet, and a total heating surface of 5395 square feet, including 300 square feet of superheater heating surface. The boilers burn oil fuel on the closed stokehold system of forced draught and each boiler is fitted with four oil sprayers. The oil burning equipment, supplied by J. I. Thornycroft and Co., Ltd., consists of a unit comprising two electric motor-driven Weir "Horzoil" rotary gears wheel pumps, two heaters, two "Auto-Klean" discharge strainers, and a "Duplex" suction strainer. Each pump has a capacity of 7500 lb per hour. Thornycroft oil sprayers and furnace fronts are installed. An electric lighting unit, designed by the White Marine Engineering Company, comprises an electric motor driven Hamworthy pump, a three-section twelve-element cylindrical heater and suction and discharge strainers. This unit can deliver 500 lb of fuel per hour at 200 deg. Fah. to ensure rapid steam raising. The control of the boiler water level is provided by Weir "Robot" feed regulators. Two single-nozzle retractable soot blowers, supplied by Clyde Blowers, Ltd., are fitted to each boiler. Klinger double-plate water level gauges and "Igema" distant-reading gauges are fitted. Two Allen geared turbo-driven forced draught fans running at 1360 r.p.m. each have a capacity of 23,000 cubic feet of air per minute at 7½in water gauge. Air trunkings fitted in the boiler-room to ensure uniform pressure and temperature conditions. An electric motor-driven fan is fitted for air supply when in dock or during lighting up.



ARRANGEMENT OF MACHINERY

Fuel is carried in five tanks, four being for boiler furnace oil and the central one for diesel oil.

The main condensers are of Weir regenerative two-flow design and have a cooling surface of 3000 square feet. They are arranged to work in conjunction with a Weir closed feed system which includes two closed feed controllers; two "Lo-Hed" two-stage, vertical spindle extraction pumps driven by 13·5 b.h.p. electric motors, each with a capacity of 80,000 lb per hour against 30 lb per square inch from suction vacuum of 28½in normal; two three-stage "Maxivac" steam-operated air ejectors; two horizontal spindle centrifugal three-stage, turbo-driven feed pumps, each having a capacity of 80,000 lb to 104,000 lb per hour; two three-flow surface type gland steam condensers with ejectors, each having a total of 30 square feet of cooling surface; an eight-flow "U" tube surface feed heater with a heating surface of 340 square feet; and a horizontal four-flow surface type drain cooler with cooling surface of 120 square feet. The two 16in turbo-driven centrifugal main circulating pumps are of the Drysdale upright type, with turbines manufactured by G. & J. Weir Ltd., each having a capacity of 4750 gallons per minute. A Weir electric motor-driven, three-throw reciprocating auxiliary feed pump with a capacity of 14,300 lb. per hour is installed.

For lighting and power, electric current is provided at 225V d.c. by three 150kW Allen diesel generators, each engine having five cylinders of 240mm bore and 300mm stroke, and developing 222 b.h.p. at 600 r.p.m. The engines have self-contained lubricating oil pumps, fresh water pumps and coolers. For circulating the fresh water through the heat exchangers there are two Allen electric motor-driven vertical spindle centrifugal pumps. The generators are started by compressed air, for which there are three air receivers, each of 11·2 cubic feet capacity, and two Hamworthy air compressors, one of which is driven by an electric motor taking current from either main or emergency circuits, while the other compressor is driven by a single-cylinder diesel engine. A 225V d.c., 35kW emergency generator, driven by a six-cylinder Ruston and Hornsby diesel engine is installed. The low power supply is provided by a motor generator and storage battery. The installation of diesel engines on the steamer was to enable the main plant to be entirely shut down while in port, a great advantage, particularly as steam can now be raised in a very short time.

Two main engine lubricating oil pumps are installed, each capable of supplying the full requirements of both engines. These pumps, supplied by Stothert and Pitt, Ltd., are vertical spindle screw displacement machines, driven by 12 b.h.p. electric motors, each having a capacity of 10,000 gallons per hour.

Among other equipment may be mentioned self-priming bilge, ballast and fire pumps; an evaporator and distiller to produce make-up feed for the boilers; a boiler for raising steam for domestic purposes; a sewage disposal plant; a complete ventilation, heating and heat and sound insulation system; fire alarm and fire-fighting and extinguishing outfit.

The vessel is fitted with the Denny-Brown ship stabiliser, as may be observed from the illustration above. Opportunity was given to test the value of this equipment thoroughly when "Normannia" was coming from the Clyde to Southampton, when she encountered some very heavy seas, and all aboard were pleased with her steadiness in a seaway.

The Flow of Wet Steam

By DENIS J. RYLEY, M.Sc. (Eng.) (Lond.), A.M.I.Mech.E.

No. II—(*Concluded from page 333, March 7th*)

For steam which remains superheated throughout expansion and for steam which remains supersaturated until it has passed the controlling section of a nozzle the ideal flow can now be computed from theories that are adequate and generally accepted. About the flow of wet steam at all times in thermal equilibrium discharge theories are confused and inaccurate. The principal existing theories are examined and a new method of approach is suggested.

IN the earliest experiments on the flow of steam through nozzles it was found that whereas the mass discharge of superheated steam conformed closely to the theoretical value when due allowance had been made for frictional effects, discrepancies occurred where wet or initially dry saturated steam was used. Careful measurement by workers such as Rateau[1] demonstrated that the actual discharge was anything up to about 5 per cent in excess of the theoretical. The effect of boundary and internal friction should have promoted a smaller and not a larger flow than that predicted by theory and researches into the matter demonstrated the existence of supersaturated flow, a phenomenon now fairly well understood.

For steam which remains superheated throughout expansion and for steam which remains supersaturated until it has passed the controlling section of a nozzle, the ideal flow can now be computed from theories which are adequate and generally accepted. There are still, however, considerable gaps in our knowledge concerning flow which is only partially supersaturated. The only published work existing to date on partly reverted steam is that due to Mellanby and Kerr,[2] although Rettaliata[3] has published data showing how a duality in the location of the Wilson line can occur from parallel experiments in which the nozzle bore roughness is the only variable. The present writer[4] has also conducted extensive experiments, as yet unpublished, on orthodox types of elementary nozzles passing partly reverted steam.

Concerning the flow of wet steam at all times in thermal equilibrium, discharge theories are confused and inaccurate, as a perusal of the following paragraphs will show. The principal existing theories are as set out hereunder.

(a) *The Equilibrium Method.*—This is the conventional method of calculating the discharge. It is assumed that supersaturation is absent and the steam becomes progressively wetter as expansion proceeds in the manner indicated by the entropy chart. No re-evaporation of the droplets, complete or partial, is assumed to occur, and a uniform temperature obtains at every individual cross section. The volume occupied by the droplets is usually neglected, and the drift velocity ratio f at the controlling section is taken as unity. Then

$$W=\frac{A_2V_2}{v_2} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where W, A, V and v have their usual meanings and the subscript $_2$ refers to conditions at the controlling section in contradistinction to inlet conditions which will later be qualified by the subscript $_1$. The area A_2 will be the effective area perpendicular to the fluid streamlines. The velocity V_2 may be calculated from (2) or (3) as follows:—

$$V_2=\sqrt{\frac{2gn}{n-1}p_1v_1\left[1-(p_2/p_1)^{\frac{n-1}{n}}\right]} \quad . \quad (2)$$

where p, g and n have their usual meanings.

$$V_2=223\cdot8\sqrt{U} \quad . \quad . \quad . \quad . \quad (3)$$

where U B.Th.U. is the adiabatic heat drop. To attach a meaning to v_1 and v_2 it is usual to take $v_1=q_1v_{s1}$ and $v_2=q_2v_{s2}$, where q is the chart dryness fraction and v_{s1} and v_{s2} refer to dry saturated steam. Substituting (2) and (3) in (1) gives

$$W/A_2=\sqrt{\frac{2gn}{n-1}\cdot p_1q_1v_{s1}\left[1-(p_2/p_1)^{\frac{n-1}{n}}\right]}\Big/q_2v_{s2} \quad . \quad (4)$$

$$W=\left\{A_2\,.\,223\cdot8\sqrt{U}\right\}/q_2v_{s2} \quad . \quad . \quad . \quad . \quad (5)$$

The expression (4) assumes that wet steam obeys the law pv^n=constant, and if $n=1\cdot035+q_1/10$ (Zeuner), this is approximately true. The expression (5) involving direct reference to an entropy chart, or a calculation from a table of the properties of steam, does not involve the perfect gas formula and will yield results of rather greater accuracy. The coefficient of discharge c_D is defined in the usual way, as the ratio of the actual discharge to the value given by (4) or (5) above.

(b) *Two-Phase Methods.*—Methods which come under this heading recognise that the value of f is not in general equal to unity, and they attempt to take cognizance of this difference by treating the droplets and the steam separately.

(i) *Method Due to Church.*—In the book *Steam Turbines*, (McGraw-Hill), E. F. Church, describes a method which does not appear in any English textbook. He works out a numerical example on the following basis.

Unit mass of steam at pressure p_1 and dryness fraction q_1 is considered (Fig. 1). The dry saturated content is considered to undergo the adiabatic expansion AB, acquiring a velocity V_{SB} and having a final dryness fraction of q_2. The discharge resulting from this is then

$$\frac{A_2V_{SB}}{q_2v_{s2}} \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Since the original quality was q_1, the total discharge is

$$W=\frac{A_2V_{SB}}{q_2\cdot v_{s2}\cdot q_1} \quad . \quad . \quad . \quad . \quad (7)$$

For the equilibrium method calculation he obtains, in the usual way,

$$W=\frac{A_2\cdot V_{SD}}{q_2\cdot v_{s2}} \quad . \quad . \quad . \quad . \quad (8)$$

Comparing the numerical results from these two expressions, (7) is found to be greater by a small amount than (8). This is due principally to the fact that the straight constant pressure lines in the wet field diverge towards the limit curve and render $AB>CD$ and thus $V_{SB}>V_{SD}$. The quantities q_1q_2 and q_2 differ by very little.

It would seem, however, that Church has overlooked the fact that the presence of q_2 in the denominator of (6) denotes droplets and that the expression assumes that all new droplets formed have f=1. Furthermore,

to divide the expression by q_1 to obtain (7) places the original droplets on the same basis as those formed during expansion and presupposes that all droplets, wherever formed, have $f=1$ at the controlling section.

In reality, this method is not a two-phase velocity method at all, but a corruption of the equilibrium method in which the difference between V_{SB} and V_{SD} has obscured the real issue.

(ii) *Method Due to Rateau[1] and Others.*—In his *Experimental Researches on the Flow of Steam and Hot Water* Rateau deals with the case of the expansion of water at saturation temperature. If water about to boil be expanded in a nozzle, any reduction in pressure brings about partial evaporation and the vapour so formed exercises an accelerating effect upon the "steam."

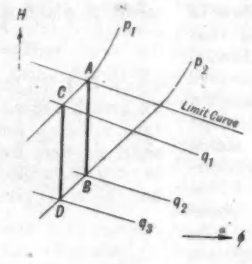


FIG. 1

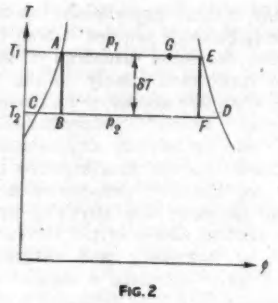


FIG. 2

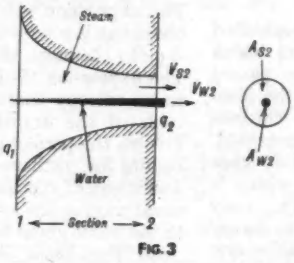


FIG. 3

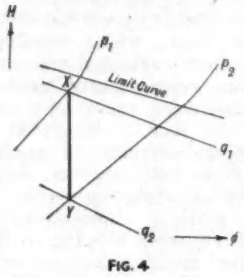


FIG. 4

FIGS. 1–4

The subject has been further investigated by others, including Hodkinson[5] and Bottomley.[6] The centre of interest now appears to have shifted to the U.S.A. and papers have been published by Benjamin and Miller[7] and by Allen,[8] respectively. For the present purpose the following basic theory may be invoked.

Considering in the first place the case of boiling water, suppose that the initial conditions are at A (Fig. 2), where the pressure is p_1. Adiabatic expansion is assumed down to pressure p_2, giving the state point locus AB. The fluid at B is "steam" of low dryness fraction, its chart value being CB/CD.

Equating the loss of enthalpy to the gain of kinetic energy,

$$\frac{V_B^2}{2gJ}=\frac{\phi_B-\phi_C}{2}\cdot\delta T \text{ (nearly)} \quad . \quad . \quad (9)$$

An improvement on the theory suggested by Hodkinson consists of taking account of the feed pump term which becomes commensurate with area ABC because of the small extent of the latter.

To extend this theory to the case of wet steam we may consider unit mass of wet steam having $q_1=AG/AE$ as the original dryness fraction (Fig. 2). The proportions of the constituents are thus q_1, $1-q_1$. The former quantity of dry steam expands yielding $q_1\cdot\frac{CF}{CD}$ of dry steam and $q_1\cdot\frac{FD}{CD}$ of new droplets, both of which for the moment may be considered to have a common velocity, V_F.

The original weight of droplets $(1-q_1)$, expands yielding $(1-q_1)\cdot\frac{CB}{CD}$ of new dry steam and leaving $(1-q_1)\frac{BD}{CD}$ of unevaporated droplets, both of which may be considered to have the common velocity V_B, which is very considerably smaller in magnitude than V_F.

We have thus arrived at the position where we have to envisage two separate mixtures, each pursuing its own independent way through the nozzle, with velocities differing by perhaps more than 1000ft per second. Such a notion clearly contravenes the dictates of common sense, and the error may be traced to the fact that thermodynamic considerations only have been invoked, whereas in fact droplets and steam must be mutually subject to dynamic interaction. Nor can any attempt be made to salvage the above theory without some considerable knowledge of the manner in which steam and droplets react together on the dynamic as distinct from the thermodynamic level. As indicated in the first article, knowledge of this subject is still fragmentary.

The above method therefore breaks down for wet steam, but gives reasonable results for hot water because the steam formed in the latter case comprises only a very small proportion of the total mass flow and the interstices between the steam and the water do not permit the steam to accelerate ahead of the water. In other words, for the hot water case, f is equal to unity.

(iii) *Method Due to Goodenough.*[9]—In his paper on "The Flow of Wet Steam," Goodenough attempted to avoid the above inaccuracies by a new approach. Using Upton's[10] expression for the maximum stable diameter of a drop

$$d=\frac{233\sigma v_S}{(V_S-V_W)^2} \quad . \quad . \quad . \quad . \quad (10)$$

where σ is the surface tension in foot-pound units, and treating a drop as a sphere subject to the usual laws of dynamics, he found a drop to have a local acceleration of

$$\frac{dV_W}{dx}=\frac{4\cdot22\,(V_S-V_W)^2}{V_W\cdot v_S} \quad . \quad . \quad . \quad (11)$$

where x represents the length of the flow path to the section under review. He effected a step-by-step integration to ascertain the distribution with x of f and to predict an ideal discharge. For the particular case treated, f was found to remain approximately constant at $\frac{1}{3}$.

Space limitations prevent a detailed criticism of this theory, but in the opinion of the present writer the method is inadequate as it is based entirely on the original droplets whose size was assumed to remain unaltered. The original droplets may only form a very small proportion of the total exit droplet population, and there will certainly be variations in the modal diameter after entrance according to the conditions encountered. There was, in fact, rather poor correspondence between the experimental and theoretical values of discharge.

(c) *A New Two-Phase Method.*—Pursuing the suggestion made in the first part of this article that dry steam and droplets might be considered separated into two discrete streams, the writer proposes a new two-phase method as outlined hereunder.

To calculate the ideal discharge, the following assumptions are made:—

(i) That steam and droplets move in an orderly manner along streamline paths, each occupying its own discrete portion of the flow area.

(ii) At a given cross-section the velocity of all steam elements is the same.

(iii) A similar condition to (ii) applies for the droplets.

(iv) The loss of enthalpy during transit is completely regained as kinetic energy in the fluid at exit.

(v) Droplets formed at any instant during the expansion are assumed to cool with the dry steam such that no re-evaporation or irreversible heat transfer occurs.

The diagram Fig. 3 represents a nozzle of any profile. It is assumed to receive wet steam at the initial conditions X as represented on the H/ϕ diagram, Fig. 4. This wet steam is taken for simplicity to be stationary, and it has a chart dryness fraction of q_1. The mixture undergoes isentropic expansion down to point Y, during which the steam acquires a velocity V_{S2} and the droplets a velocity of V_{W2}.

Total mass of mixture/sec. crossing Section 2:

$$W=\frac{A_{S2}V_{S2}}{v_{S2}}+\frac{A_{W2}V_{W2}}{v_{W2}}.$$

Since

$$f_2=V_{W2}/V_{S2},$$

$$W=V_{S2}\left(\frac{A_{S2}}{v_{S2}}+f_2\cdot\frac{A_{W2}}{v_{W2}}\right) \quad . \quad . \quad (12)$$

Also

$$q_2=\frac{A_{S2}V_{S2}/v_{S2}}{V_{S2}\left(\frac{A_{S2}}{v_{S2}}+f_2\cdot\frac{A_{W2}}{v_{W2}}\right)} \quad . \quad . \quad (13)$$

Since $A_2=A_{S2}+A_{W2}$, (13) may be rearranged and simplified to give the area wholly occupied by dry steam as

$$A_{S2}=\frac{f_2v_{S2}A_2}{v_{W2}\left(\frac{1}{q_2}-1\right)+f_2v_{S2}} \quad . \quad . \quad . \quad . \quad (14)$$

Then the area occupied wholly by water is

$$A_{W2}=A_2\left[1-\frac{f_2\cdot v_{S2}}{v_{W2}\left(\frac{1}{q_2}-1\right)+f_2v_{S2}}\right] \quad . \quad (15)$$

Now, the original enthalpy of the mixture when at X was $h_1+q_1L_1$ per unit mass. In unit time, however, the emergent mass W is as given by (12). The original enthalpy of the emergent mass is therefore

$$V_{S2}\left[\frac{A_{S2}}{v_{S2}}+f_2\cdot\frac{A_{W2}}{v_{W2}}\right][h_1+q_1L_1] \quad . \quad (16)$$

The enthalpy on emergence will be the sum of the respective enthalpies of the dry steam and droplets, viz.,

$$\frac{A_{S2}V_{S2}}{v_{S2}}\cdot H_{S2}+\frac{A_{W2}V_{W2}}{v_{W2}}\cdot h_2 \quad . \quad . \quad (17)$$

where H, L, h have their usual meanings. The difference between (16) and (17) will

have reappeared as kinetic energy in the mixture, thus:

$$V_{S2}\left[\frac{A_{S2}}{v_{S2}}+f_2\frac{A_{W2}}{v_{W2}}\right][h_1+q_1L_1]$$
$$-\left[\frac{A_{S2}V_{S2}}{v_{S2}}\cdot H_{S2}+\frac{A_{W2}V_{W2}}{v_{W2}}h_2\right]$$
$$=\left[\frac{A_{S2}V_{S2}}{v_{S2}}\cdot\frac{V^2_{S2}}{2gJ}+\frac{A_{W2}V_{W2}}{v_{W2}}\cdot\frac{V^2_{W2}}{2gJ}\right].$$

Simplifying and extracting V_{S2} this becomes

$$V_{S2}=\sqrt{\frac{2gJ\left\{\frac{A_{S2}}{v_{S2}}[h_1+q_1L_1-H_{S2}]+f_2\cdot\frac{A_{W2}}{v_{W2}}[h_1+q_1L_1-h_2]\right\}}{\sqrt{\frac{A_{S2}}{v_{S2}}+\frac{A_{W2}}{v_{W2}}\cdot f_2^3}}} \quad . \quad (18)$$

Finally, by (18) in (12)

$$V_{S2}=\sqrt{\frac{2gJ\left\{\frac{A_{S2}}{v_{S2}}[h_1+q_1L_1-H_{S2}]+f_2\cdot\frac{A_{W2}}{v_{W2}}[h_1+q_1L_1-h_2]\right\}}{\sqrt{\frac{A_{S2}}{v_{S2}}+\frac{A_{W2}}{v_{W2}}\cdot f_2^3}}}\cdot\left[\frac{A_{S2}}{v_{S2}}+f_2\cdot\frac{A_{W2}}{v_{W2}}\right] \quad . \quad (19)$$

This expression may be tested for the special case wherein $f_2=1$.

Thus, putting $f_2=1$ in (18) and rearranging gives

$$V_{S2}=\sqrt{\frac{2gJ\left\{\left(\frac{A_{S2}}{v_{S2}}+\frac{A_{W2}}{v_{W2}}\right)(h_1+q_1L_1)-\left(\frac{A_{S2}}{v_{S2}}\cdot H_{S2}+\frac{A_{W2}}{v_{W2}}\cdot h_2\right)\right\}}{\sqrt{\frac{A_{S2}}{v_{S2}}+\frac{A_{W2}}{v_{W2}}}}} \quad . \quad (20)$$

The factor

$$\left(\frac{A_{S2}}{v_{S2}}\cdot H_{S2}+\frac{A_{W2}}{v_{W2}}\cdot h_2\right)$$

may be rewritten as

$$\left(\frac{A_{S2}}{v_{S2}}+\frac{A_{W2}}{v_{W2}}\right)h_2+\frac{A_{S2}}{v_{S2}}\cdot L_2 \quad . \quad (21)$$

Since

$$q_2=\frac{A_{S2}/v_{S2}}{\frac{A_{S2}}{v_{S2}}+\frac{A_{W2}}{v_{W2}}}$$

for this case, (21) may be written as

$$\left(\frac{A_{S2}}{v_{S2}}+\frac{A_{W2}}{v_{W2}}\right)(h_2+q_2L_2) \quad . \quad (22)$$

If, now, (22) be introduced into (20) and simplified, one obtains

$$V_{S2}=\sqrt{2gJ\{(h_1+q_1L_1)-(h_2+q_2L_2)\}} \quad . \quad (23)$$

Examination of (23) shows immediately that this is the usual expression for the velocity of expanding steam under equilibrium conditions.

Examination of the general expression (19) reveals that for a given nozzle operating with isentropic expansion between given terminal conditions, the only variable is f_2. In circumstances where the probable value of f_2 is approximately known, it may be inserted into (19) and a reasonably exact prediction made of the ideal flow.

Owing, however, to the limitations of present knowledge, f_2 will not, in general, be approximately known. In such a case the following procedure may be adopted. Expression (19) may be written as

$$W=\psi(f_2)$$

On differentiating, the first derived function, $\psi^1(f_2)$ is readily obtained. It will be found on examination that in the range $0<f_2<1$, $\psi(f_2)$ yields a single maximum value obtained by using the value of f_2 given by solving $\psi^1(f_2)=0$.

Unfortunately the expression (19) is unwieldy and not well suited for a symbolic exploration of its properties. It may, however, be shown that the value of f_2 which makes (19) a maximum is given by $\sqrt[3]{v_{W2}/v_{S2}}$. Since v_{W2} varies very little for a wide range of normal pressures, this may be taken as $0{\cdot}25/\sqrt[3]{v_{S2}}$.

The above theory may best be clarified by an example, the data for which is taken from the writer's experiments.

Example. Area of nozzle at controlling section (A_2), 0·001277 sq ft; $p_1=85{\cdot}7$ lb per square inch absolute, $q_1=0{\cdot}97$ by measurement, $p_2=0{\cdot}578\dagger\times85{\cdot}7=49{\cdot}5$ lb per square inch absolute.

From *Steam Tables* (Callendar, 1939):

$h_1+q_1L_1=1158{\cdot}5$ B.Th.U. per lb.
$v_{W1}=v_{W2}$ (assumed)$=0{\cdot}0173$ cubic feet per lb.

After isentropic expansion to critical conditions,

$v_{S2}=8{\cdot}603$ cubic feet per lb.
$H_{S2}=1174{\cdot}8$ B.Th.U. per lb.
$q_2=0{\cdot}9365$
$h_2=249{\cdot}6$ B.Th.U. per lb.

From (14) and (15),

$$\frac{A_{S2}}{v_{S2}}=\frac{0{\cdot}001277f_2}{0{\cdot}001173+8{\cdot}603f_2}$$

$$A_{W2}=0{\cdot}001277\left[1-\frac{8{\cdot}603f_2}{0{\cdot}001173+8{\cdot}603f_2}\right].$$

By substitution and simplification in (18),

$$V_{S2}=\sqrt{\frac{45{\cdot}3}{1+0{\cdot}0678f_2^2}}.$$

By substitution and simplification in (19),

$$W=\frac{2{\cdot}05}{\sqrt{1+0{\cdot}0678f_2^2}\cdot\left(\frac{0{\cdot}001173}{f_2}+8{\cdot}603\right)}.$$

Denoting the denominator by D, extracting dD/df_2 and equating to zero gives the optimum value of $f_2=0{\cdot}126$. By resubstitution, the maximum discharge is found to be 0·238 lb per second.

The measured discharge was 799 lb per hour.

The discharge coefficient is thus $799/3600\times0{\cdot}238=0{\cdot}932$.

A curve showing the variation of W with f_2 is given to an extended vertical scale in Fig. 5. An additional curve shows the proportions of flow area passing respectively water and steam. The most noticeable thing about the W/f_2 curve is that for a wide range of values of f_2 the discharge is affected very little. If f_2 is increased from 0·13 to 1·0, the discharge is decreased by approximately 3 per cent. At very low values of f_2, however, the term $0{\cdot}001173/f_2$ assumes increasing importance and W declines sharply. Such low values would, however, impose impossible physical conditions, and this decline is only of academic interest.

Returning to the percentage increase in W consequent upon the decrease of f_2 from 1·0 to 0·13; this 3 per cent, whilst not great in itself, may be of importance in considering discharge coefficients which may themselves only be spread over a range of 10 to 15 per cent for very varied kinds of nozzles. We have here taken the view, in default of information about f_2 to the contrary, that the ideal nozzle shall discharge the maximum possible weight under given terminal conditions and, hence, the ideal value of f_2 will be the appropriate value, whether or not it falls within the probable practical range. The present value of 0·13 is likely to be much smaller than ever occurs in practice. Also for given terminal conditions, f_2 is quite beyond the control of the designer.

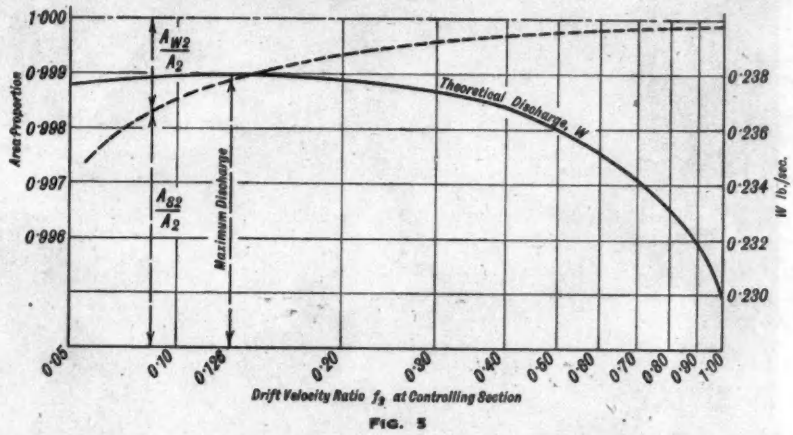


FIG. 5

A comparison of the values of ideal discharge obtained by this method and by the expression (5) is of interest. If $f_2=1$ in both cases, the ideal discharge as predicted by the present method is very slightly smaller than that predicted by (5) because of the area correction in the former. The new method, however, adjusts the value of f_2 to make W a maximum, and the effect of this more than offsets the area correction at moderate pressures such that greater values of flow result from the use of the new method at the optimum value of f_2. At some high value of f_2, the two effects cancel and each method predicts the same ideal flow. The value of f_2 at which this takes place is probably quite close to the experimental value for most cases. Thus, for flow in thermal equilibrium, the equilibrium method gives a more accurate value than hitherto.

A number of criticisms may legitimately be levelled at this new theory. Thus, it may justly be contended that if $f_2<1$, the steam is overtaking the droplets and frictional losses at their surfaces must result which invalidates assumptions (iv) and (v), as it introduces irreversibility and promotes reduction of the flow. If the criterion of excellence is the complete absence of frictional effects and therefore reversibility, this is incontestibly true, but if the criterion is the maximum flow of fluid as appropriate to considerations of discharge, the matter is more obscure. Although no exact information exists concerning the dissipation of energy as surface friction on drops, it may be safely inferred to be very small.‡ If and when it is known, a coefficient can readily be introduced into (18). It probably happens, therefore, that with a value of f_2 other than

† As appropriate to expansion below critical back pressure.

PROGRESS OF THE BRISTOL "BRITANNIA" AIRLINER

THE PROTOTYPE "BRITANNIA" AIRLINERS

THE FUNCTIONAL MOCK-UP ASSEMBLY

unity, the discharge is disproportionately increased, thus more than offsetting the flow reduction arising from surface friction. The optimum value of f_2 may, however, be greater than that given by differentiation in the above manner. But the droplet population is very sparse, and the drops have smooth surfaces and are probably nearly spherical.

It may also be objected that the dynamic interaction of steam and droplets which was shown to invalidate previous two-phase theories is also overlooked in this new theory. This criticism is largely untrue as the cumulative mutual effects during transit define the final value of f_2.

Finally, it may be contended that to separate water and steam into two discrete uniform streams is a serious over-simplification, and that whereas the steam characteristics at a given section may be reasonably uniform, the droplets will show a wide disparity as regards size and velocity. This is at once admitted, and, indeed, the above theory does not purport to be in any way rigorous. The modest claim made on its behalf is that it is an advance on existing two-phase theories as it avoids some of the anomalies explored in earlier paragraphs. This advantage is, unfortunately, gained at the expense of considerable complication. Any rigorous theory would have to take cognisance of differences in drop size, velocity, &c., and would have to be approached from a statistical standpoint. Existing knowledge of the behaviour of drops is quite inadequate to enable such a theory to be elaborated.

REFERENCES

[1] Rateau, *Experimental Researches on the Flow of Steam and Hot Water*. 1905. Constable.
[2] Mellanby and Kerr, *Proc. I.Mech.E.*, 1922, page 855.
[3] Rettaliata, *Trans. A.S.M.E.*, Vol. 58, 1936, page 599.
[4] Ryley, THE ENGINEER, page 633, December 2, 1949.
[5] Hodkinson, *Engineering*, Vol. 143, June 4, 1937.
[6] Bottomley, *Trans. N.E. Coast Institution of Engineers and Shipbuilders*, December, 1936.
[7] Benjamin and Miller, *Trans. A.S.M.E.*, Vol. 64, 1942, page 657.
[8] Allen, *Trans. A.S.M.E.*, Vol. 73, 1951, page 257.
[9] Goodenough, *Power*, September 27, 1927.
[10] Upton, *Sibley Journal of Engineering*, January, 1923.

Conducting Coatings on Glass

WE learn that the National Physical Laboratory has developed a method of coating glass with a thin transparent film which is electrically conducting. The film can be heated by passing a current through it and it can, therefore, be used to keep aircraft windscreens free from ice or snow. The coating is a very thin layer of a metal oxide. Tin is one of the metals that has given good results. It can be deposited evenly on the glass by techniques that are familiar to industry. The glass is then heated to near the softening point and cooled again, which oxidises the tin and makes the coating transparent. Finally the film is washed in water and dried, a process which increases its conductivity. The film is hard, adheres firmly to the glass surface and is resistant to chemical attack.

For all practical purposes the reduction in visibility through the glass because of the metal coating is negligible. The film has a resistance of about 1000 ohms between the opposite sides of an inch square. Enough current can be passed through it to keep the surface free from ice or condensation. For this purpose the film would be sandwiched between two thicknesses of glass. Glass coated by the process described can also be used to avoid the accumulation of static charges on the windows of instruments when they are cleaned in dry weather. This accumulation of charge can cause serious inaccuracies in indicating instruments and it was to remove this source of error that the research and development of coated glass was initiated at the N.P.L.

Ceramic materials can be coated as well as glass and there are many possible applications for the process in the electrical industry.

‡ This view is supported by Keenan, *Trans. A.S.M.E.*, 1934, Vol. 1, page 431.

The Bristol "Britannia" Airliner

It is expected that the first prototype of the Bristol "Britannia" class airliner will fly later this year and some constructional details are given herewith. An extension of the practice whereby the testing in mock-assemblies of engine installations and ancillary systems proceeded in advance of the completion of the prototype has led to the construction of a partially complete non-flying prototype known as a "functional mock-up," which is described.

THE development and assembly of the "Britannia" air liner, which, together with its engines, is made by the Bristol Aeroplane Company, Ltd., have so advanced that the maiden flight of the first prototype is expected to take place this summer.

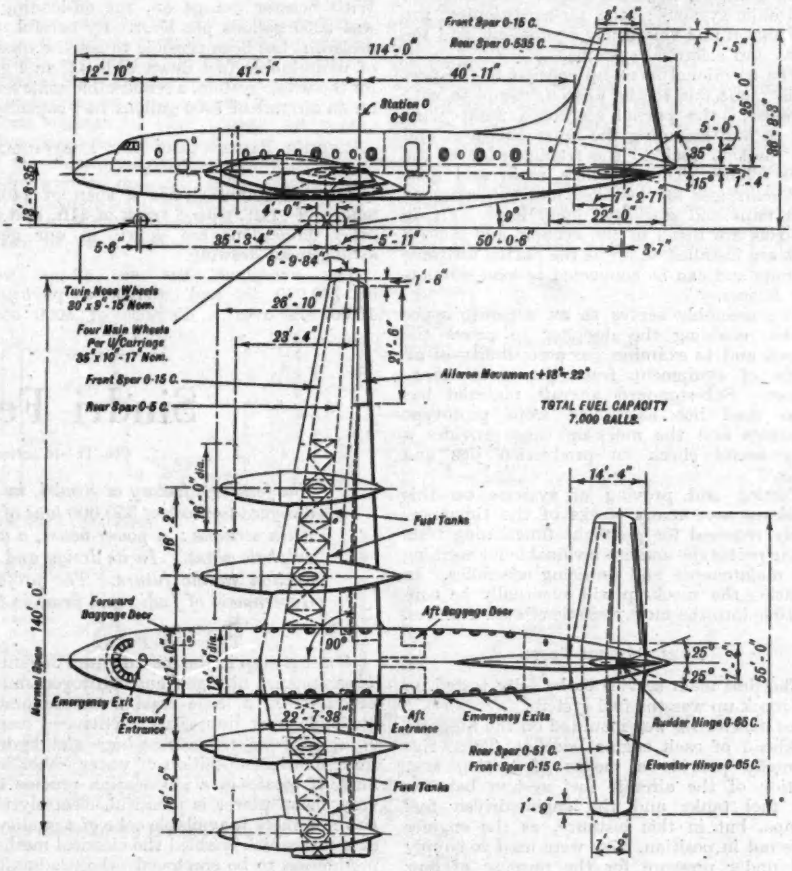
In the light of this progress the company has disclosed some interesting details of the work already carried out on the two prototypes ordered by the Ministry of Supply and illustrated herewith, and upon the mock-up and other sub-assemblies.

As already announced, the British Overseas Airways Corporation has ordered twenty-five "Britannia" aircraft, fitted with "Proteus" propeller-turbine engines, for service on trunk routes to Australia and South Africa. These aircraft are intended to begin operation in 1954–55.

This comprehensive programme of research and manufacture, which is now nearing completion, has involved the construction and study of a number of special components and structures for test purposes.

Those assemblies which have been specially built are a full-scale engineering mock-up, known in the company as the "functional mock-up," a full-scale wing specimen, complete with engine nacelles and a representative section of fuselage, for structural tests; a half-scale fuselage specimen, also for structural tests; a front fuselage specimen, 30ft in length, for pressure tests; and scale-model tab-operated control surfaces fitted to and flight-tested on a Bristol "Freighter" for comparison with wind-tunnel tests on various models. These models include a one-eighth scale model of the complete aircraft and a one-third scale model of the tail unit, both of which have been investigated in the 24ft wind tunnel at the Royal Aircraft Establishment, Farnborough.

Extensive research has also been undertaken on propellers, engine controls and landing gear, and on the hydraulic, electrical, radio, air-conditioning and de-icing installations. Some of this work has been carried out by the Bristol Aeroplane Company's associates and some by leading specialists in the industry. At all stages close liaison has been maintained with



Wings:	
Gross area	2055 square feet
Span nominal	140 feet
Aspect ratio	9·53
Standard mean chord	14ft 8in
Taper ratio	3·33/1
Setting to body datum (at root)	+3 deg.
Root section	NACA 23017
Tip section	NACA 4413 MOD
Geometric twist	2·4 deg.
Ailerons:	
Area each (including tabs)	70 square feet
Span each	21ft 6in
Flaps:	
Area total	410 square feet
Maximum angle down	50 deg.
Body:	
Length	114ft
Maximum diameter	12ft
Gross surface area	3416 square feet
Fin and rudder:	
Area clear of body (including rudder, excluding dorsal)	315·4 square feet
Dorsal area	41 square feet
Rudder area (including tabs)	92·2 square feet
T/C ratio	0·125
Tailplane and elevators:	
Gross area (including elevators)	588 square feet
Aspect ratio	5·15
Elevators area each (aft of H.L.) (including tabs)	85 square feet
Span	55ft
Setting to body datum	Neutral
T/C ratio	0·125

FIG. 1—GENERAL ARRANGEMENT OF BRISTOL "BRITANNIA" AIRLINER

the Ministry of Supply and the British Overseas Airways Corporation.

The "Functional Mock-Up"

The full-scale engineering mock-up of the "Britannia," known at Filton as the "functional mock-up," is an extended application of a procedure hitherto applied only to certain assemblies, such as hydraulic systems, folding-wing mechanisms for naval aircraft, and cockpit and nose-wheel assemblies, which involve particular problems of assembly, mechanical efficiency and accessibility for maintenance.

It is stated by the company that the "Britannia" is probably the first civil design for which so extensive a functional mock-up has been built. The idea was used to some extent in the development of the "Brabazon" power plant and landing gear installations, the former being described by J. L. Norton in his paper, "The Twin 'Centaurus' Plant for the 'Brabazon' Aircraft," an abstract of which was published in The Engineer, April 27, 1951, pages 542, 543, 589 and 590; problems which would otherwise have arisen in pre-flight tests of the prototype were eliminated.

The functional mock-up is, in effect, a non-flying prototype. It is fully representative in detail and dimensional accuracy, to a degree which cannot be obtained on a wooden mock-up, and is also a test rig on which various systems can be given exhaustive working tests before assembly in the prototype itself.

Among the systems which can be tested on the functional mock-up are the engine and flight controls, including flaps; the fuel and hydraulic systems; the air-conditioning, fire precaution and emergency equipment, and the radio and electrical systems.

The functional mock-up consists of the port main plane out to the aileron, complete with nacelles; the partial starboard main plane out to and including the inner nacelle; and the fuselage back to the trailing edge of the main plane. The complete main and nose undercarriages are installed and the complete port flaps and starboard inner flaps. Flying controls are fitted in the cockpit and control runs are installed as far as the partial airframe permits and can be connected to load-simulating devices.

The assembly serves as an accurate space model, enabling the designer to prove the layout and to examine the accessibility of all items of equipment from the maintenance aspect. Sub-standard aircraft material has been used but assembled from prototype drawings and the mock-up thus provides a very useful check on production jigs and tools.

Testing and proving of systems on this mock-up save many weeks of the time normally required for pre-flight functioning tests of the prototype and are invaluable for working out maintenance and servicing schedules. In addition the mock-up will eventually be convertible into the most realistic of crew trainers.

Fuel System Tests

The first main service to be fully tested on the mock-up was the fuel system.

An exacter rig was mounted on the fireproof bulkhead of each engine nacelle. These rigs normally provide a means of testing that portion of the aircraft fuel system between the fuel tanks and the engine-driven fuel pumps, but in this instance, as the engines were not in position, they were used to supply fuel under pressure for the purpose of flow checks, &c. In most of the checks only 10 per cent of the total fuel capacity was used, the fuel normally fed to the engine being returned to the filler opening.

The whole of the mock-up can be tilted, as shown in our second illustration and held in various attitudes which might be obtained in sustained flight, that is, 15 deg. climb and 3 deg. dive, both in combination with 5 deg. sideslip port and starboard. All main tests were carried out in each of these attitudes.

Flow tests were divided into two phases. Flows were measured under gravity feed to the collector boxes from each tank and in all the above attitudes, and were then repeated with booster pumps switched on. The tests were again repeated with the balance cocks open and the cross feeds were checked. The maximum consumption of kerosene per engine is 280 gallons per hour, to which is added a 25 per cent factor, making the test requirement 350 gallons per hour per engine. In all cases this figure was easily reached. It will be appreciated that the permutations and combinations of the above tests alone make a very formidable programme. To this, moreover, must be added tests of the venting system, although final clearance on this system cannot be given until the flight trials, which will prove whether the vent to atmosphere is in the correct position.

The pressure refuelling system was also tested on the functional mock-up. A check was made on the balance pipes between the flexible bag tanks which must each be capable of withstanding the refuelling pressure of 50 lb per square inch. A safety valve is embodied in each refuelling bag.

A jettison outlet is placed under the wing trailing edge and is retractable, being power-operated by an actuator. Here again, although the mock-up made possible tests of the system, final proof can only be given by flight trials. The system is so arranged that, after jettisoning, 500 gallons will remain in the tanks.

Off-loading, such as might be required through a last-minute change in flight plan, can be accomplished through the pressure refuelling points by using the booster pumps, when maximum flow is required, or by gravity. With booster pumps on, the off-loading rate was 2253 gallons per hour. By careful detail design, it has been possible to get the quantity of undrainable fuel down to less than 1 gallon for the whole system, a remarkable achievement on an aircraft of 7000 gallons fuel capacity.

Leading Particulars and Performance Data

The "Britannia" has a span of 140ft, a length of 114ft, with a track of 31ft, and some other dimensions are shown in our general arrangement drawing.

The aeroplane has an all-up weight of 140,000 lb and carries a payload of 25,000 lb over a distance of 4000 statute miles in still air, at a mean cruising speed of 360 m.p.h., and a mean altitude of 30,000 ft. The maximum range in still air with standard tanks is 5600 statute miles, for which a payload of 12,000 lb can be carried.

At take-off, all engines operating, it can clear a 50ft obstacle at a distance of 3700ft when taking-off against a 5 m.p.h. wind at sea level. (This distance increases to 6400ft (1950m) in an ambient temperature of 27 deg. Cent., at a pressure altitude of 5500ft.) The aeroplane can land over a 50ft obstacle within a distance of 2800ft in a 5 m.p.h. wind at sea level.

Seating Arrangements

The method of seat attachment makes possible a large variety of seating arrangements and three typical loading cases are quoted. The seat pitch being adjustable in small increments, when arranged for first-class transport it can be fitted with individual seats placed four abreast to carry fifty passengers, with weight allowances as follows:—

	lb
Fifty passengers at 160 lb each	8,000
Passengers' hand baggage at 5 lb each	250
Passengers' heavy baggage at 55 lb each	2,750
Consumable stores (9 lb per passenger)	450
Freight, mail, bullion or extra fuel	13,550
	25,000

This version could therefore carry fifty passengers and their baggage and 13,550 lb of freight for 4000 statute miles, or fifty passengers and their baggage non-stop between London and New York on 80 per cent of occasions under existing weather conditions; and between New York-London at all times.

When arranged for second-class travel, accommodation is arranged with five abreast seating for sixty-one passengers, there being a corresponding reduction to 11,031 lb freight or extra fuel allowance.

With third-class or coach seating and passenger weight allowances as before, 104 passengers seated six abreast can be carried, but over much shorter ranges.

Comprehensive air conditioning, pressurising and thermal de-icing equipment are installed, to suit different climatic conditions. Full radio and navigational aids, including search radar and the "zero" reader, are all fitted.

Sindri Fertiliser Factory

No. II—(*Continued from page 339, March 7th*)

The fertiliser factory at Sindri, in India, which has now been officially opened, is designed to produce 350,000 *tons of ammonium sulphate a year. It consists of four main sections: a power-house, a gas plant, an ammonium synthesis plant, and a sulphate plant. In its design and layout provision has been made to increase production in the future. The project is an example of co-operation between the Government of India and firms in this country and the United States.*

The Gas Plant

As a first step in the manufacture of synthetic ammonia, nitrogen and hydrogen must be produced on a large scale from economically available raw materials. Nitrogen can be obtained from the atmosphere and hydrogen from the decomposition of water either in the form of steam in a gasification process or, if very cheap power is plentiful, electrolytically. In India there is available coke of a quality and at a cost which enabled the classical method of production to be employed—the production of water gas from coke, the necessary nitrogen being obtained by introducing an air-steam mixture during the gas-making phase of the cycle of operations, followed by carbon monoxide conversion and carbon dioxide removal. In the conversion plant carbon monoxide is oxidised to carbon dioxide, steam being simultaneously decomposed to provide additional hydrogen, so that, after the removal of carbon dioxide, the correct hydrogen to nitrogen ratio of 3 : 1 for ammonia synthesis is achieved.

The gas plant at Sindri, which is to be seen in one of the illustrations, was designed and supplied by the Power-Gas Corporation, Ltd., to suit local conditions and consists of eight generator units. When gasifying suitable coke it is capable, with seven generators working, of producing daily 33 million cubic feet of gas of the following typical analysis:—CO_2, 6·5 per cent; $CO+H_2$, 69·8 per cent; CH_4 +argon, 0·8 per cent; and N_2, 22·9 per cent.

As the Bihar coke has a high ash content, nearly 500 tons is required daily, together with 500 tons of steam to give the required output. One of the diagrams on page 369 shows the flow of fuel and then gas through the plant. Run-of-oven coke is delivered either to a storage dump or to the crushing and screening plant, where it is reduced to a size of 3in to 4in before delivery to overhead bunkers at the gas plant by belt conveyors. Each of the eight water gas generators in this plant is fitted with an automatic cyclic coke charger. These chargers, one of which is shown in an illustration on page 370, screen and weigh the coke charged to the generators, and are controlled through the hydraulically operated controller described below.

Each mechanical generator consists of a large cylindrical steel vessel, the upper part of which is brick-lined and the lower part boiler-jacketed. It has a revolving dry baseplate

GAS PLANT AT SINDRI

supporting a grate through which the blast is introduced to the fuel bed, and ash boxes through which the ash is extracted for discharge into railway wagons below. Steam generated in the boiler jackets at 20 lb per square inch is available for use in the gasification process and provision has been made for the addition of waste heat boilers should they prove economical under future conditions.

The gas-making cycle consists essentially of blow and run periods, during which the fuel bed is alternately heated by the introduction of air alone and cooled during gasification.

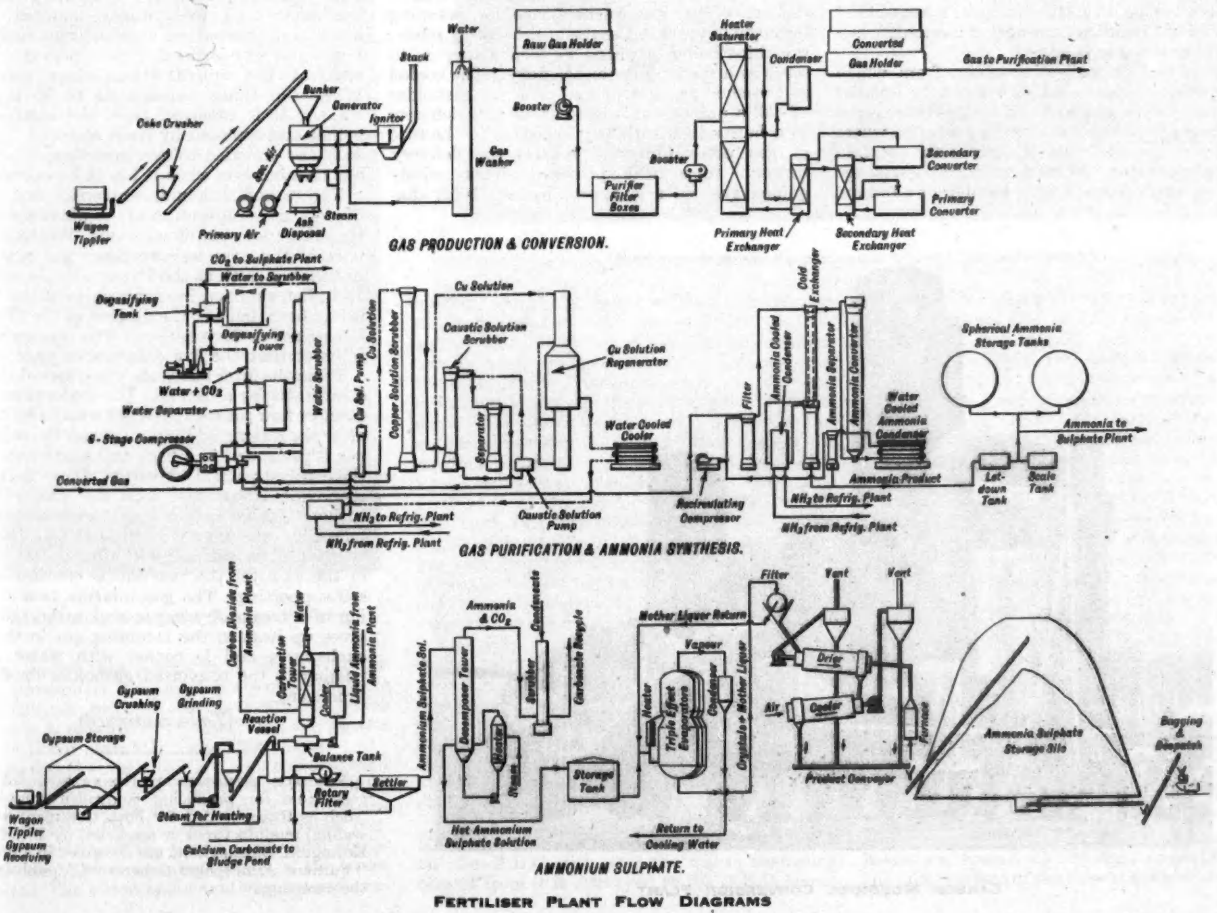
This cycle of three to four minutes' duration is automatically carried out on each generator by a hydraulic controller, which ensures uniform production at constant efficiency with a minimum wastage of time during the cycle for valve operation. A control unit is shown in one of the illustrations on the next page. The hydraulic system operates at a pressure of 1000 lb per square inch, which makes it possible to keep the size of equipment necessary for operation of each individual valve within reasonable limits. Interlocks are incorporated in the hydraulic units to prevent a dangerous sequence or combination of valve operations. The generators are designed to operate continuously except for a short standby period which is necessary during each shift for emptying the ash boxes and examination of the fuel bed.

The cycles of the eight generator units are stepped in sequence to provide continuity of output. In the initial blow period of a cycle primary air passes upwards through the generator and the resulting products of combustion, which contain a proportion of carbon monoxide, can be burnt with a supply of secondary air whilst passing downwards through the igniter before discharge through the stack to atmosphere. During this period the chequerwork in the igniter is heated up ready for superheating the steam supply. In the subsequent blow purge period the gas-making process is actually started with the stack open to atmosphere for a short time to purge out, if necessary, blow gases from the system.

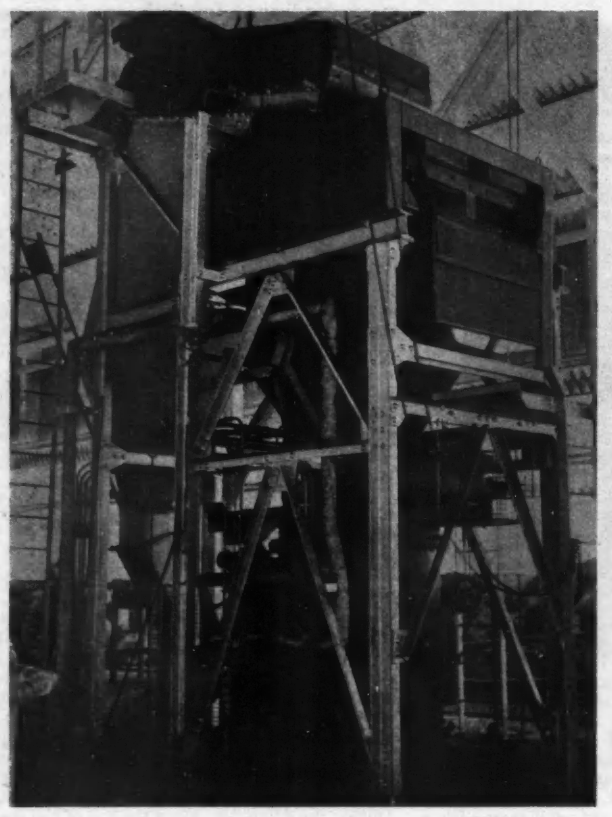
The initial up run then starts when steam and air are admitted at the bottom of the generator, and the gas produced passes out through the top gas control valve and connections to the seal box and gas collecting main. The proportion of air admitted is adjusted to provide the required amount of nitrogen in the make gas.

To control the condition of the fuel bed it is necessary to arrange that a proportion of the steam passes downwards through the fuel bed, and, in a following down run period, steam is admitted to the bottom of the igniter, to be superheated as it passes through the chequer brickwork before passing downwards through the generator. No auxiliary air is used during this period, i.e., blue water gas only is generated. During the down run, when the top of the generator is filled with steam, the opportunity is taken to introduce fuel through the two interlocking valves of the automatic cyclic charger, which is hydraulically operated by the same system as the gas, air and steam control valves.

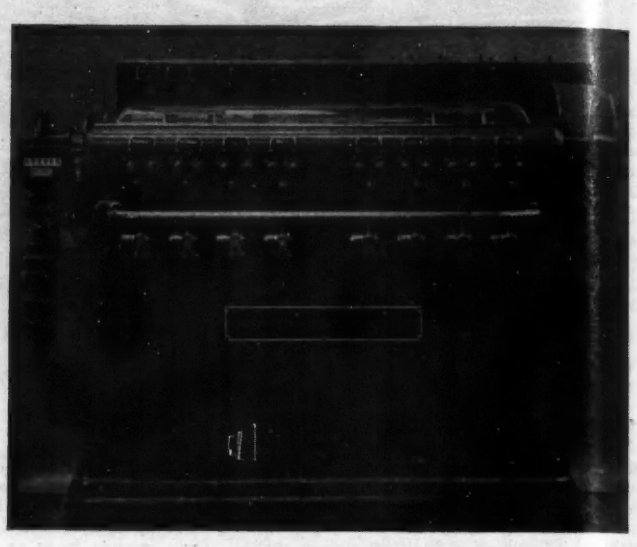
A final up run is the same as the initial up run except that normally no air is introduced. The



FERTILISER PLANT FLOW DIAGRAMS



GAS GENERATOR CHARGING GEAR



GAS GENERATOR CONTROL UNIT

cycle is completed by a run purge, which is a return to the blow period, but with the stack valve temporarily closed so that water gas remaining in the system can be sent forward to the gas collecting main.

The gas plant, with seven generators working and one acting as a standby unit, is capable of producing 33 million cubic feet of gas daily when gasifying suitable coke.

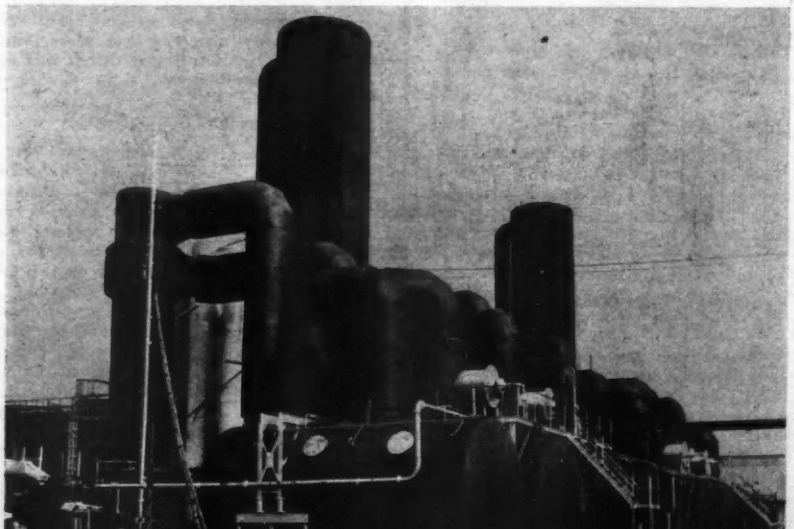
From the gas collecting main, from which each generator unit can be completely isolated by means of a water seal box, the gas is delivered to three gas washing and cooling towers, where it passes upwards, counter-current to a stream of cooling water. In its downward passage the cooling water passes over a number of alternate cones and discs to ensure its intimate contact with the gas. Some 200,000 gallons of cooling water maintained in circulation through the gas washing system is recirculated through a settling tank and over a cooling tower. This arrangement ensures that only a relatively small amount of make-up water is required. Equipment is provided for the addition of soda ash solution to the system for partial removal of H_2S at the same time as the gas is washed and cooled. Three circulating pumps are installed, one for pumping from the cold well to the top of the gas washers, one for pumping from the hot well to the top of the cooling tower, the third being arranged in such a way as to serve as a standby for either duty. The cooled and washed gas is delivered to a raw gasholder of half a million cubic feet capacity, which acts as a buffer to absorb any variation in the rate of gas production and control the delivery through subsequent processes. This spiral-guided gasholder is approximately 100ft diameter by 100ft high when its three lifts are fully extended. Alarm and shut-down equipment is installed to operate when the contents of the gasholder reach approximately 90 per cent or drop to about 10 per cent of its full capacity.

From the raw gasholder the gas is delivered by boosters through two purifier filter boxes filled with over 1000 tons of iron oxide purification material. These filter boxes reduce the solid impurities and the remaining hydrogen sulphide content of the gas to a degree suitable for carbon monoxide conversion. The gas flow can be arranged to pass through both boxes in parallel or through one alone. A controlled quantity of air is introduced to the gas stream before it enters the boxes for revivification of the iron oxide in situ, the oxygen reacting with iron sulphide formed, regenerating to iron hydroxide and precipitating sulphur. The oxide is supported on wooden grids inside the boxes and an overhead crane is provided for its removal for revivification when necessary. When the oxide contains 35 to 45 per cent sulphur it is removed from the system altogether and replaced by fresh material. Water seals are provided to give complete isolation of one or other box when it has to be opened.

The carbon monoxide conversion and carbon dioxide removal section of the plant is shown in the accompanying illustrations. Whilst it forms part of the complete synthesis gas producing installation such as the Power-Gas Corporation, Ltd., has supplied in many parts of the world, it has been built to the designs of the Chemical Construction Corporation. The process can be followed from the flow diagram on page 369.

From the filter boxes the gas is forced through a saturator by a blower. Hot water pumped in counter-flow saturates the gas with moisture and after the further addition of steam the saturated gas is preheated in a heat exchanger and enters the catalyst packed converter, where the carbon monoxide is oxidised with the production of carbon dioxide and hydrogen according to the following reaction: $CO+H_2O=CO_2+H_2$. This reaction is exothermic and after initial heating of the catalyst the reaction is continuous and self-supporting. The gas mixture now consisting of nitrogen, hydrogen and carbon dioxide, gives up heat to the incoming gas in the heat exchangers and is cooled with water before passing to the converted gasholder for further processing.

(*To be continued*)



CARBON MONOXIDE CONVERSION PLANT

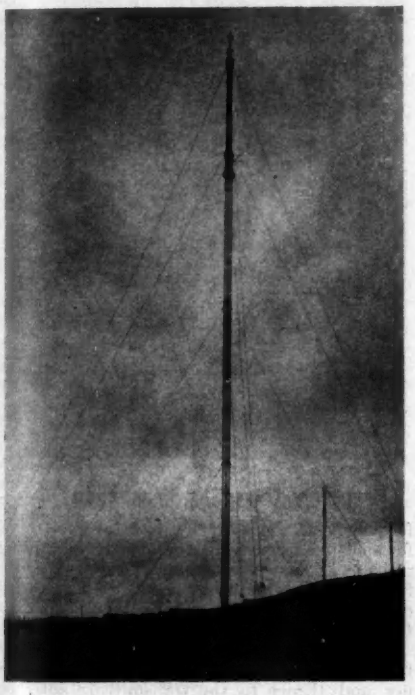
FURNACE ATMOSPHERE GENERATORS.—Various generators for producing controlled atmospheres (such as those needed for heat treatment without scaling) manufactured or marketed by Birlec, Ltd., Erdington, Birmingham, are described in a brochure "Furnace Atmosphere Generators," published by the company.

Kirk o' Shotts Television Transmitting Station

Regular programme transmissions from Kirk o' Shotts are due to begin to-day, using the medium-power vision and sound transmitters, which will provide an experimental service until the high-power transmitters are completed later in the year. This article describes the station with its medium-power equipment, the coaxial cable links between Alexandra Palace, Birmingham and Manchester, and the microwave radio link between Manchester and Edinburgh.

KIRK o' SHOTTS transmitting station is about midway between Glasgow and Edinburgh, on a site 900ft above sea level, and the 750ft mast brings the total height of the vision and sound aerials to over 1600ft. Until the high-power transmitters are ready the service will be given by medium-power vision and sound transmitters, using the main mast and aerial system.

The vision transmitter will operate on a frequency of 56·75 Mc/s (5·3m) and the sound transmitter on 53·25 Mc/s (5·635m). These medium-power equipments, which will ultimately be kept as standby plant, form a separate installation, housed in the annexe building. The medium-power vision transmitter is a low level modulated equipment with a peak white output power of 5kW. Modulation is carried out at the 500W level and the signals are then amplified by two class "B" wide-band linear r.f. amplifiers, each using a pair of forced-air-cooled triodes. Appropriate shaping of vestigial side-band signals radiated by the vision transmitter is carried out in its own circuits, and not by a separate vestigial side-band filter, as in the case of the high-power transmitter. All valve filaments are a.c. heated, with the exception of those in the modulated amplifier and the linear amplifiers which derive their supply from metal rectifiers. The transmitter h.v. supplies are obtained from hot cathode mercury vapour rectifiers, which provide a maximum of 3000V for the anodes of the linear class "B" amplifier stages.



MAIN AND STANDBY AERIAL MASTS

The sound transmitter is a conventional class "B" modulated unit with an output of 2kW. All valve filaments are a.c. heated. As in the case of the vision transmitter, the crystal controlled drive and the power conversion equipment are built as an integral part of the transmitter. The vision and sound outputs are combined in a Maxwell bridge diplexer combining unit next to the transmitters, and the combined output is fed into the main aerial transmission line system at a point close to the mast base. Both transmitters are contained in similar sheet steel cubicles mounted side by side and so present a single continuous front in the transmitter hall. One of our illustrations shows, on the right, the five cubicles that make up the vision transmitter; and, further to the left, two of the three sound transmitter cubicles. The air blast cooling equipment and combining filter are mounted behind the transmitter cubicles, which are built into a soundproof partition wall, so as to isolate the noise of the air blowers from the control desk situated immediately in front of the transmitters.

Both transmitters are controlled and monitored from this desk, which incorporates a built-in waveform monitor and two picture monitors besides the conventional controls and meters. With these two picture monitors the incoming signals can be compared with those radiated. Programme switching for both sound and vision circuits is accomplished at this desk. The controls of each transmitter are sequence-interlocked to ensure that the various supplies are applied in the correct order and, where necessary, with the appropriate time interval between each. Next to the control desk are the vision and sound programme input equipment bays and the test waveform generating equipment, which provides a variety of signals for testing, lining up and maintaining the characteristics and performance of the vision transmitter.

MEDIUM-POWER SOUND AND VISION TRANSMITTERS

The vision programme is received at the station over the G.P.O. distribution network, which consists of a 1in tube coaxial cable system from London to Birmingham, a ⅝in tube coaxial cable system between Birmingham and Manchester, and a radio-relay link between Manchester and Kirk o' Shotts. Further details of these transmission links are given in the concluding section of this article.

The Post Office radio receiving terminal at Kirk o' Shotts is housed in a separate building on the B.B.C. site and the video frequency output from it is conveyed to the B.B.C. transmitting station by a short length of ⅝in coaxial tube.

The sound programme reaches Kirk o' Shotts over specially equalised G.P.O. telephone circuits similar to those used for other B.B.C. transmitting stations.

The mast and aerial systems, which are designed to accept the full power from the main transmitters, are of generally similar construction to those already in use at Sutton Coldfield and Holme Moss. As illustrated, the mast is stayed at four levels by three locked coil steel wire ropes spaced equidistantly around it; it weighs 140 tons and the total downward thrust, including that due to the stays, is 336 tons. The circumferences of the stays range from 4¾in to 6in and the breaking loads are up to 210 tons. The structure can withstand a wind load of 80 tons, which corresponds to an 80 m.p.h. wind at the base rising to 120 m.p.h. at the top, allowing for 23½ tons of ice distributed over the mast, corresponding to a coating ½in thick overall. Under these conditions the mast head would move 7ft 6in from the perpendicular.

For the first 610ft the mast is of triangular section, each side being 9ft across. From 610ft to 710ft it is cylindrical and has slots cut in its surface, which would ultimately form a very-high-frequency aerial for sound broadcasting should this system be installed at Kirk o'Shotts in the future. Surmounting the cylindrical section is a topmast carrying the two tiers of four vertical dipoles which form the combined vision and sound aerial. To prevent icing each dipole incorporates an electric heater, controlled from the ground.

A separate 150ft mast carries the emergency aerials system for use in the event of a breakdown in the main aerial or transmission line. The emergency aerials are separately fed and switches are provided to enable a rapid changeover to be made from the main to the standby system.

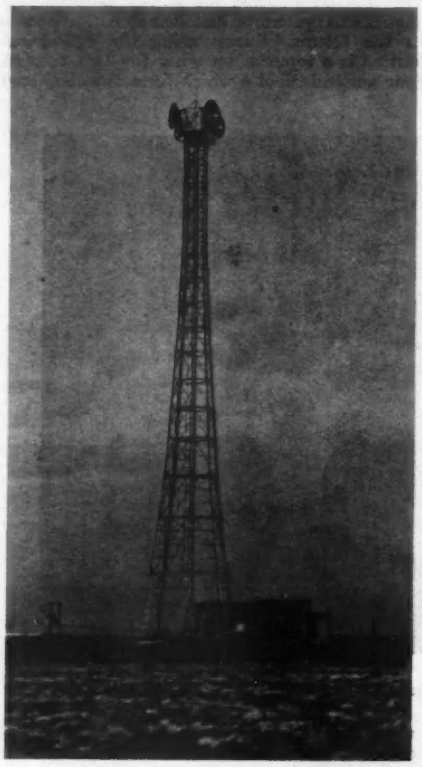
At Kirk o' Shotts, as at Holme Moss, the outputs of the main vision and sound transmitters are combined at ground level and a single transmission line is used to convey this combined output to the common aerial system at the top of the mast. The transmission line for Kirk o' Shotts is of novel construction. It is a coaxial copper tube, in which the inner tube has been replaced by a locked coil wire rope, the outer layer of wires being made of high-conductivity copper. This rope, together with the 5in diameter copper tube forming the outer conductor, is suspended pendulum fashion from a support at the top of the mast. The wire rope is tensioned at the lower end by a loading mechanism designed to apply a force of approximately 2 tons. The rope is located coaxially with the outer conductor by small rod insulators, spaced at 120 deg., projecting from the inner surface of the tube at suitable intervals.

This design of transmission line has a very high degree of electrical uniformity, which is a necessary characteristic of lines intended for wideband television transmission.

Power for operating the station is drawn via duplicate feeders from the South-West Scotland Electricity Board's 11kV, three-phase, 50 c/s network and the pressure is reduced to 415V by duplicate 500kVA step-down transformers, which, together with the h.v. switchgear, metering equipment and main l.v. switchgear, are installed in the annexe building.

The main station building contains the offices, canteen, quality checking room, power distribution switchgear and the accommodation for the high-power transmitters, the installation of which is now in progress. It is similar in design to the previous stations at Sutton Coldfield and Holme Moss and is constructed from a local Scottish brick relieved with stone dressings, harmonising well with its surroundings. The roof is formed from precast hollow beams covered with a screed of concrete, a special roofing felt and finished with tar-macadam.

The medium-power transmitters will provide satisfactory service over a considerable area of



REPEATER STATION AT BLACKCASTLE HILL

Central Scotland, including Edinburgh and Glasgow; but reception will, of course, be more liable to interference, particularly in fringe areas, than it will be when the high-power transmitters come into service.

Coaxial Cable Links

Between London and Birmingham the main television link is provided by coaxial cable consisting of a main cable and a short tail cable at each end: it follows the route of the old Roman Road via Watford, Aylesbury, Daventry, Coventry, and Birmingham. The main cable, forming part of the Post Office trunk telephone network, covers a distance of just over 121 miles, with forty-three repeater stations *en route*, of which eleven are required for present-day programmes. It terminates at Museum Exchange, London, and Telephone House, Birmingham, and the end connections, to the transmitters are provided by tail cables between Museum Exchange and Alexandra Palace and between Telephone House and Sutton Coldfield.

The London - Birmingham cable incorporates two 0·975in and four 0·375in coaxial tubes. The larger tubes are used, with repeaters designed and made by the G.P.O. at 12-mile spacing, for two-way transmission of 405-line television signals requiring a video bandwidth of approximately 3 Mc/s. Ultimately these tubes may be required for very high definition or colour television and frequencies up to 26 Mc/s may be involved with repeaters at 3-mile spacing. The 0·375in tubes are used for broadband telephony purposes, each pair being capable of carrying 600 speech circuits. The whole system has been planned to meet the recommendations of the 1943 Television Committee.*

Between Birmingham and Manchester there is another coaxial cable (illustrated opposite). It includes six 0·375in tubes, of which two are used for the transmission of video signals, sixteen paper-insulated quads for controlling the repeater stations associated with the coaxials and 172 paper-insulated quads for local telephone traffic. The repeater stations, with equipment designed and installed by the G.P.O., are spaced at about 6-mile intervals. Beyond Manchester the cable extends through Hyde to Mottram and from Mottram to Holme Moss the television network has been completed by means of a two-tube coaxial spur cable containing four screened pairs for music circuits and twenty-four paper-insulated quads for repeater control, in addition to the two 0·375in coaxial tubes.

Vestigial sideband terminal equipment is used with this cable link to translate the video signals to a frequency band suitable for transmission over the coaxial cable. The vestigial sideband principle consists in the modulation on a carrier of the video band and the transmission over the cable of the whole of one sideband plus a vestige of the other sideband. This small but significant part of the other sideband enables the video-frequency band to be shifted appropriately without greatly increasing the transmitted band beyond that of the video band and, incidentally, obviates the very difficult technical problems involved in the single-sideband transmission of television signals.

The Manchester-Edinburgh Microwave Radio Link

The newest link in the chain is from Manchester to Kirk o' Shotts. It is a two-way microwave radio relay link which operates on the general principle of beamed microwave transmissions at a frequency of the order of 4000 Mc/s or a wavelength of 7·5cm, over a series of optical paths along a carefully planned and surveyed route connecting the two terminal stations. The total length of this route is 250 miles. The preliminary survey, carried out with portable microwave television links of the kind used for a number of B.B.C. "outside television broadcasts" during 1950 and 1951, confirmed calculated heights for transmitter and receiver antennæ as well as their spacing along the route. Accordingly, each individual microwave transmission traverses an average distance of some 30 miles, a total of seven repeater stations being provided for receiving an re-transmitting programme signals *en route*.

Terminal and repeater stations are equipped to give one unidirectional channel from Manchester to Kirk o' Shotts simultaneously with a second similar channel in the reverse direction. Each channel is designed to handle the 0–3 megacycles bandwidth of a 405-line definition, fifty frames per second, double-interlaced television programme in one direction of transmission. Full remote control and supervisory facilities are provided whereby each terminal station is able to control the operation of the equipment at all points along the route to the other terminal.

To ensure a high degree of reliability all transmission equipment with the exception of parabolic reflectors and main waveguide feeds is provided in duplicate; the changeover from one set of equipment to the other being fully automatic in the event of breakdown. In the same way, automatic standby sources of power supply have been provided to cater for a break-down in local public mains supplies.

The intermediate two-way repeater stations are designed to work unattended. Should the occasion arise, however, they could be adapted so that locally derived programme material could be injected into the network for transmission in either or both directions. In this way the Manchester-Edinburgh link not only extends the television service to new areas, but can also facilitate programme contributions to that service from the intermediate areas.

Transmitting equipment for the microwave radio link at Kirk o' Shotts and Manchester is designed to accept the video-frequency bandwidth of 0–3 Mc/s at a level of 1V D.A.P.† in 75 ohms. The video signal modulates the reflector-cathode circuit of a reflex klystron oscillating at a basic frequency of the order of 4000 Mc/s, in such a way that the output

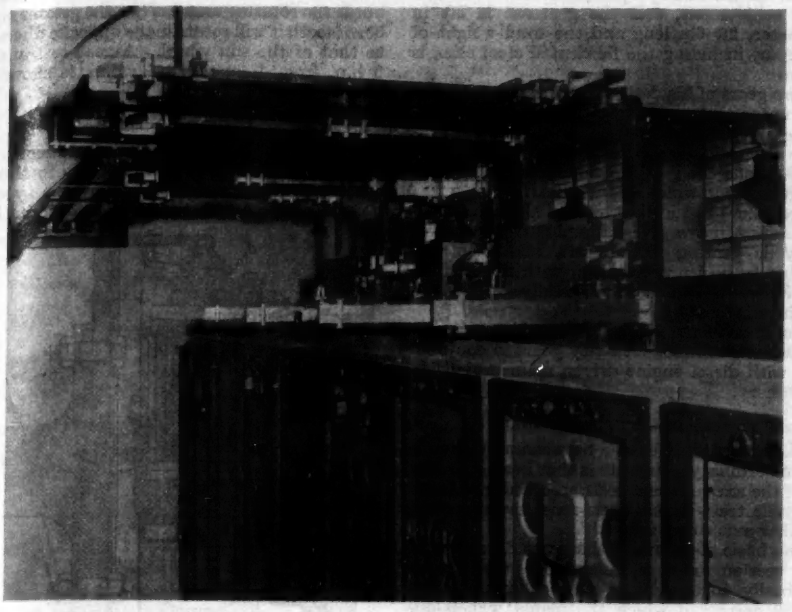
REPEATER TOWER AT BLACKFORD HILL

frequency is deviated by a total of 6 Mc/s for a change from the bottom of a synchronising pulse to a peak white picture. The r.f. oscillator frequency is stabilised by means of a precision crystal oscillator with a basic or fundamental frequency of the order of 20 Mc/s.

The s.h.f. output from the klystron is fed through waveguides to a travelling wave amplifier and thence to the transmitting antenna. Transmitting and receiving antennæ at the terminal and repeater stations consist of waveguide horns feeding paraboloids which are 10ft in diameter and mounted on steel towers, two paraboloids at each of the terminals and four at each repeater station. The heights of these towers range from 20ft to 200ft, depending on the altitude of the site in relation to the terrain covered by the beamed transmission. The width of each transmitted beam is $\pm 1\frac{1}{2}$ deg. to the half-power points and the waveguide feed delivers a power of 1W to the antenna. We illustrate the tower at Blackford Hill near

* The 1943 Television Committee recommended in its report (1945) that after the war the 405-line system should be reinstated in London and extended first to Birmingham and then to other provincial centres. It also recommended, among other things, that developments be planned on the assumption that a higher definition system, perhaps incorporating colour, would for some time be operated side by side with the present system.

†D.A.P. (double amplitude peak) is the peak-to-peak amplitude of the television signal.



WAVEGUIDE LAYOUT AND CUBICLES AT REPEATER STATION

Edinburgh and the 200ft tower at Blackcastle Hill, near Dunbar.

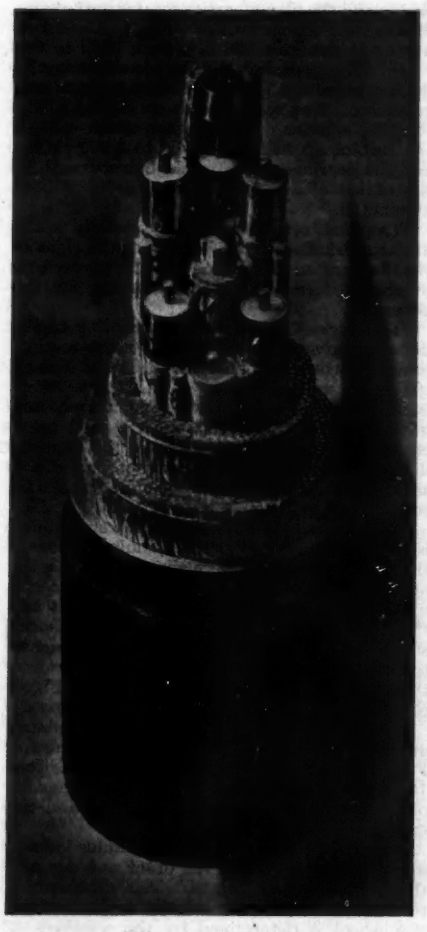
On arrival at the first repeater the frequency modulated s.h.f. wave is passed by a waveguide feed from the parabolic reflector to a superheterodyne receiver. This receiver employs a crystal controlled local oscillator operating at a frequency of 60 Mc/s above the mid-frequency of the incoming signal (or 57 Mc/s above the incoming frequency corresponding to synchronising pulses) to produce an intermediate frequency band centred on 60 Mc/s. The i.f. signals are amplified in an amplifier fitted with a.v.c. and again translated to a radio frequency 37 Mc/s above or below the incoming r.f. An automatic frequency control maintains the frequency of the second local oscillator 37 Mc/s above or below that of the first local oscillator. Unwanted products of the last process are eliminated by means of a filter, the required single sideband being amplified by a travelling wave amplifier to a power of 1W and passed to the transmitting antenna.

This process is repeated at each successive repeater station until the other terminal of the link is reached. There the s.h.f. band from the antenna is passed to a superheterodyne receiver. This receiver, as in the case of the repeaters, uses a crystal controlled local oscillator to produce an i.f. band centred on 60 Mc/s. Thereafter, however, the output from the i.f. amplifier is frequency demodulated in a discriminator which converts the frequency modulated i.f. band to the video frequency range. This is then available at a level of 1V D.A.P. in 75 ohms for passing either directly to a television transmitter or further radio link, or via a vestigial sideband system to a coaxial cable network.

To eliminate mutual interference due to multiple path effects two radio frequencies are employed, being used in alternate directions on alternate sections. They differ from each other by about 37 Mc/s.

The waveguides and waveguide circuit elements, such as attenuators, filters, hybrid-type junctions and switches carrying s.h.f. waves, have a rectangular cross section of approximately 2in by $\frac{1}{2}$in and are made of either brass or copper. The waveguide run from the equipment racks to the horn feed is filled with dry nitrogen maintained under slight pressure to preserve the inside surface of the guide from corrosion. Inside the equipment racks it would be inconvenient to fill with nitrogen and maintain a hermetic seal and the waveguide surfaces are protected by gold plating instead of the varnish-finish used for the main run.

An interesting aspect of the complete link is the detailed precautions which are taken to avoid interruption of the service. They include duplication of the majority of the equipment with automatic change-over to standby equipment immediately on failure of the working equipment. In addition, provision is made for remote switching of equipment from control stations at Kirk o'Shotts and Manchester, where the condition of equipment at each station is displayed continuously on a control board. A four-wire land line circuit interconnects all terminal and repeater stations and provides a party line speaker circuit and a two-tone v.f. telegraph circuit which carries the supervisory and remote control signals. There is a remote control desk at Kirk o'Shotts, with testing and monitoring apparatus, which affords full indications of serviceability and the position of switchgear at all repeater stations along the route for both directions of transmission with full control over incoming signals. A similar remote control desk at the Manchester terminal affords identical remote control and switching facilities for the opposite direction of transmission with full supervision at all points for both directions of transmission.



STEPPED SECTION OF BIRMINGHAM–MANCHESTER COAXIAL CABLE

Equipment at all stations operates normally from the local three-phase a.c. mains supplies; dynamic voltage regulators stabilising the output voltage to within ±1 per cent of nominal are provided for each phase. A diesel engine alternator set, is arranged to start up and take over the load automatically within fifteen seconds of a failure of the public mains supply.

PRINCIPAL CONTRACTORS

Plant.—5kW vision transmitter and 2kW sound transmitter, Marconi's Wireless Telegraph Company, Ltd.; aerials and medium-power vision and sound transmitter combining filter unit, Marconi's Wireless Telegraph Company, Ltd.; main transmission lines and high-power vision and sound combining filter, Electric and Musical Industries Research Laboratories, Ltd.; main low-voltage switchgear, Brush Electrical Engineering Company, Ltd.; 11kV/415V transformers, English Electric Company, Ltd.; high-voltage switchgear, Switchgear and Cowans, Ltd.; auxiliary low-voltage switchgear, Standard Telephones and Cables, Ltd.; valve cooling and ventilation, Rosser and Russell, Ltd.; coaxial cable to reserve aerials, Telegraph Construction and Maintenance Company, Ltd.

The high-power vision and sound transmitters, the installation of which has not yet been completed, were designed and manufactured by Electric and Musical Industries, Ltd., and Standard Telephones and Cables, Ltd., respectively.

Civil Engineering and Buildings.—Masts (750ft and 150ft), British Insulated Callender's Construction Company, Ltd.; roads and buildings, M'Lean and Co., Ltd.

Programme Links.—The G.P.O. was responsible for the provision of the programme link and the associated control equipment; main contractors to the G.P.O., Standard Telephones and Cables, Ltd.

Epicyclic Gears*

By H. N. G. ALLEN, M.A., and T. P. JONES

No. I

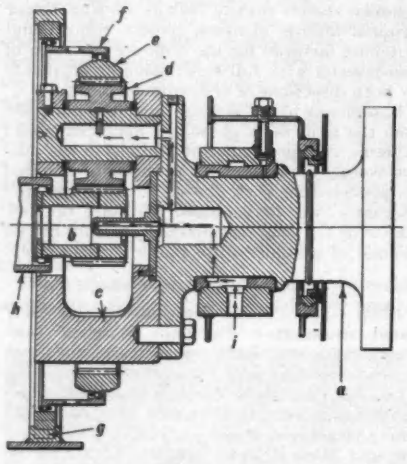
IN mechanical engineering it is not unusual to find that many of the basic ideas which are now common practice are based on fundamental principles which have been known for many centuries. There are also numerous cases where ideas have been patented in the very early stages of mechanical engineering development and have lain unused because of the difficulties of practical application or methods of construction, or because the theory has not been fully understood.

The story of epicyclic gearing is no exception to this historical trend and, in 1781, James Watt patented a sun and planet gear which he utilised in his early engines, to convert reciprocating motion into rotary motion without infringing existing patents on the crank mechanism. Epicyclic gearing was freely used during the 19th century, but did not keep pace with the demand for larger powers, because improvements in the technique of cutting external gears outstripped developments in the production of internal gears. Further, the difficulties in ensuring that the planet wheels shared the load were either not appreciated or could not be overcome, because it was not possible to make and measure the components with the required

* The Institute of Marine Engineers, Tuesday, March 11th. Abstract.

degree of accuracy and none of the co-axial members was allowed to float.

Early in this century, the advantages to be obtained from a compact and "in-line" gear were appreciated by the pioneers of automobile engineering. By way of example, one has only to mention the Model "T" Ford, the early Lanchester cars and, more recently, the gear pioneered by W. G. Wilson, who mentioned in a paper a three-speed compound epicyclic gear

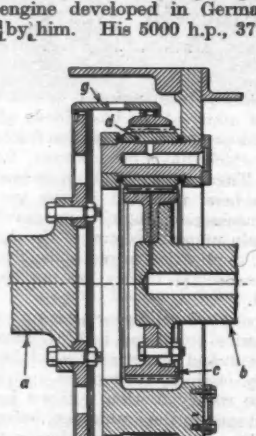


(*a*)—Low speed shaft.
(*b*)—Sun wheel.
(*c*)—Planet carrier.
(*d*)—Three planet wheels.
(*e*)—16-in p.c. diameter annulus.
(*f*)—Double toothed flexible coupling ring fixing annulus to gearcase.
(*g*)—Torque reaction from gear taken by key at horizontal joint of gearcase.
(*h*)—Part of flexible coupling connecting sun wheel to rotating annulus of first train star gear.
(*i*)—Oil inlet.

FIG. 1—5 : 1 *Planetary Gear*

constructed in 1920 for a trawl winch, transmitting 170 h.p. at 170 r.p.m., which was still running satisfactorily in 1932.

In industrial fields, epicyclic gears for high speeds or large torques have not been extensively used in this country until recent years, but this form of gear has had quite extensive use on the Continent, particularly in Germany. This is largely due to the study of the problem by W. G. Stoeckicht, who designed and applied epicyclic gearing, not only in long life industrial engineering but also in the aircraft and marine fields. The 3300 h.p., 3200 to 1170 r.p.m. gears for the "Jumo 222," the largest piston-type aircraft engine developed in Germany, were designed by him. His 5000 h.p., 3770 to 580



(*a*)—Low speed shaft.
(*b*)—High speed shaft.
(*c*)—Sun wheel.
(*d*)—Six star wheels.
(*e*)—Star wheel carrier.
(*f*)—16-in p.c. diameter annulus.
(*g*)—Double toothed flexible coupling ring fixing annulus to low speed shaft.

FIG. 2—1·6 : 1 *Star Gear*

r.p.m. marine main propulsion gear is a remarkable achievment, and the gearcase is 3ft in diameter, 2ft 6in long and the total weight of the gear, including the fabricated steel case, is 1 ton.

Two gears of his design are running on turbo-alternator sets. They are double helical planetary gears and the sun and planet wheels have been nitrided in both cases, and in both applications the governor is almost as large as the gearcase to which it is attached.

Propeller gas turbines, with their high speeds of rotation, have given stimulus to the use of epicyclic gearing for aircraft, and there are lessons to be learned which, with appropriate modification, can be successfully applied to marine engineering.

Small reversing epicyclic gears have been in constant use for some twenty years in conjunction with diesel engine driven main propulsion machinery.

Types of Epicyclic Gears

The essential difference between an epicyclic and an ordinary gear train is that in an ordinary train the axes of the wheels are fixed, but in an epicyclic train at least one axis moves around another axis which is fixed.

The basic elements of the gears described in this section are: a central sun wheel; an internally toothed gear ring or annulus; a planet carrier in which the planet wheels are supported; a planet wheel or wheels engaging with the sun pinion and/or annulus.

There are many possible forms and combinations of epicyclic gears. Here it is proposed to describe five types only, one of which is not a true epicyclic, and one or two of the possible combinations of these.

So far as the authors know, there are no generally accepted terms for the kinds which are to be described and for the sake of convenience, therefore, these will be referred to as "planetary" "star," "solar," "compound planet" and "double annulus" gears respectively.

Planetary Gears.—The annulus is fixed to the casing and the planet carrier rotates in the same direction as the sun wheel. Fig. 1 shows such a gear to transmit 600 h.p. from 3000 to 600 r.p.m. The gear shown is the second train of a double reduction gear between a turbine and generator. The sun wheel is connected to the rotating annulus of a star gear which reduces the turbine speed from 16,500 to 3,000 r.p.m., and the bearings which would be necessary for the pinion of a parallel shaft gear have been eliminated.

The planet carrier is bolted up solidly to the armature shaft and the bearing at the right of the illustration, from which the planet carrier is overhung, forms the second bearing for the generator.

Star Gears.—The star gear, according to the definition given at the beginning of this section, is not a true epicyclic gear, although it is of the same general form. In this gear there is no relative motion between the axes of any of the wheels. The planet carrier is fixed in the casing and the annulus rotates in the opposite direction to that of the sun wheel, and Fig. 2 shows a gear to transmit 550 h.p. from 1000 to 625 r.p.m.

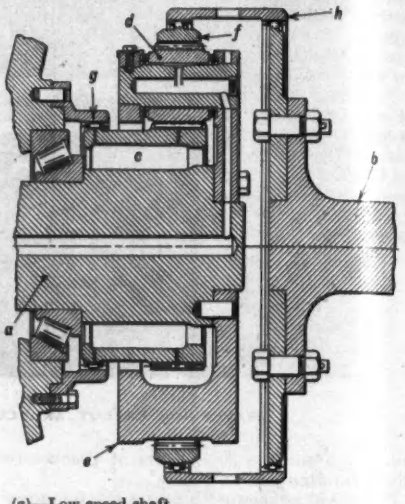
Solar Gears.—In a solar gear the sun pinion is fixed to the casing and the annulus rotates in the same direction as the planet carrier. In the other gears illustrated and described, the sun wheel is attached to the high speed shaft and the other rotating member to the low speed shaft, but in this gear the annulus is attached to the high speed shaft and the planet carrier to the low speed shaft. The gear shown in Fig. 3 is to transmit 550 h.p. from 1000 to 625 r.p.m.

Compound Planet Gears.—A compound planet gear may be used equally well for star gears, and Fig. 4 shows a gear to transmit 72 h.p. from 16,000 to 775 r.p.m. This is the arrangement of a reduction gear between a turbine and circulating pump for marine use.

Double Annulus Gears.—One annulus is fixed in the casing and both the other annulus and the planet carrier rotate. The direction of rotation of the annulus relative to that of the sun wheel is determined by the numbers of teeth in the two annuli. If the annulus which has the smaller number of teeth is rotating it will do so in the same direction as the sun wheel, but if the rotating annulus has the greater number of teeth it will rotate in the opposite direction to that of the sun wheel. A gear to transmit 6 h.p. from 1500 to 13·5 r.p.m. is shown in Fig. 5.

Choice of Gear

In addition to the fact that the direction of rotation of the output shaft relative to that of the input shaft is determined by the type of epicyclic gear fitted, there are also limitations



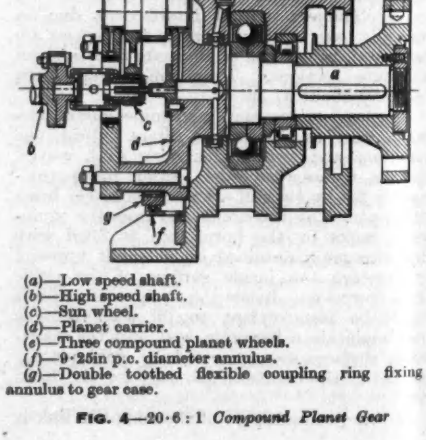
(*a*)—Low speed shaft.
(*b*)—High speed shaft.
(*c*)—Sun wheel.
(*d*)—Five planet wheels.
(*e*)—Planet carrier.
(*f*)—15·625in p.c. diameter annulus.
(*g*)—Single toothed flexible coupling ring fixing sun wheel to gear case.
(*h*)—Double toothed flexible coupling ring fixing annulus to high speed shaft.

FIG. 3—1·6 : 1 *Solar Gear*

with regard to the ratio which may be obtained. Planetary gears are suitable for ratios from 3 : 1 to 12 : 1, star gears for ratios between 2 : 1 and 11 : 1, solar gears for ratios between 1·2 : 1 and 1·7 : 1, compound planet gears for ratios of 11 : 1 to 25 : 1, and double annulus gears for ratios from 25 : 1 to 1600 : 1.

In certain cases it is possible to use more than one gear for a given ratio. For example, both the star gear shown in Fig. 2 and the solar gear in Fig. 3 have the same ratio and each of these forms a reduction train in otherwise identical main propulsion reversing gearboxes. They were designed to give opposite rotation for the two propellers of a twin-screw ship in which both diesel engines have the same rotation.

In addition to the tooth reaction loads taken by the planet bearings in planetary and solar



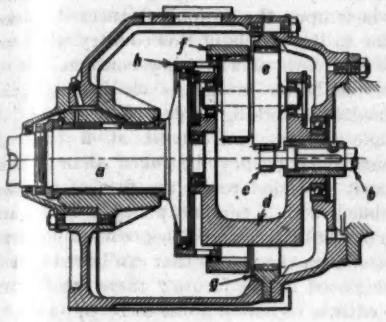
(*a*)—Low speed shaft.
(*b*)—High speed shaft.
(*c*)—Sun wheel.
(*d*)—Planet carrier.
(*e*)—Three compound planet wheels.
(*f*)—9·25in p.c. diameter annulus.
(*g*)—Double toothed flexible coupling ring fixing annulus to gear case.

FIG. 4—20·6 : 1 *Compound Planet Gear*

gears, there is also a centrifugal load on the planet bearings and for this reason these gears are not suitable for high speeds of rotation of the planet carrier.

Star gears are normally used when the low speed shaft rotates at 3000 r.p.m. or more. The ratio of the planetary gear is $\frac{A}{S}+1$ and of a star gear $\frac{A}{S}$, and consequently the annulus of a star gear is larger than that of a planetary gear for the same ratio.

Solar gears may be used to obtain lower



(a)—Low speed shaft.
(b)—High speed shaft.
(c)—Sun wheel.
(d)—Planet carrier.
(e)—Three compound planet wheels.
(f)—Rotating annulus.
(g)—14·25in p.c. diameter annulus.
(h)—Double toothed flexible coupling ring fixing rotating annulus to low speed shaft.

FIG. 5—111 : 1 *Double Annulus Gear*

ratios than those which it is possible to achieve with star or planetary gears.

Care must be taken in the design of compound planet gears because the use of a compound planet wheel gives rise to a tipping moment on the planet wheel bearings. This arises because the tooth load at the sun wheel-planet contact is not in the same plane as that of the planet-annulus contact.

Double annulus gears are generally more efficient than worm gears and may be used where the concentric arrangement of input and output shafts is desirable.

(*To be continued*)

Vibrations in Marine Engineering

A PAPER entitled "Vibrations in Marine Engineering" was read before the Institution of Engineers and Shipbuilders in Scotland, by A. E. Fothergill, B.Sc., on January 29th, and is summarised below.

New forms of propelling machinery and new methods of ship construction have introduced vibration problems which have been and are the subject of much research and there is need for the correlation of the accumulated data. The two main classes of vibration met in practice are those occurring within the machinery without affecting the surrounding structure and those set up by the machinery having objectionable effects upon the ship's hull. The first group includes torsional, longitudinal and lateral vibrations, transverse engine vibration and singing propellers, while vertical and horizontal vibration of the whole ship, torsion vibration of the hull, local vibrations and noise fall within the second category.

A historical survey of the various investigations into vibration problems is given and the early work of Schlick, Yarrow, Tweedy and Dalby is mentioned, while the names of Lockwood-Taylor, Todd, Burrill and Prohaska are linked with more recent investigations. The present state of knowledge of hull vibration periods is reviewed, special attention being paid to torsional vibrations in the machinery, in which torsional vibration characteristics can be predicted within the limits of $\pm 2\frac{1}{2}$ per cent for 1-node and ± 5 per cent for 2-node frequencies. For natural frequencies the trial and error tabular process is suggested. One of the doubtful factors is the practice of adding 25 per cent to the propeller inertia to allow for water effect, while approximate formulæ for calculating propeller inertias in air may give wide discrepancies.

In motorships the second and higher nodes are affected by the torsional stiffness of the crankshaft and the varying turning effort of the engine. The importance of the effect of the phase relationship between blades and cranks upon vibratory torque is emphasised. For calculating vibration stresses for 1-node, where the main source of damping is the propeller, the magnitude can be estimated from known characteristics, but for 2 or more nodes the propeller amplitude is small and only engine damping and shaft hysteresis require consideration.

Usually fitted at the free end of the crankshaft, the Bibby detuner serves to reduce torsional vibration stresses and another design in use is the Houdaille viscous damper. This consists of a heavy disc, free to revolve on a shaft, fitted inside a casing filled with a silicone fluid. Instrumentation for measuring torsional vibration such as torsiographs and electronic apparatus is briefly discussed.

With regard to hull vibration excited by engines the causes of transverse vibration with high-speed rotating parts of turbine machinery are touched upon and then the problems of reciprocating engines are dealt with, while the characteristics giving rise to vertical and horizontal vibration are noted. The use of Lloyd's exciter to subject the hull to periodic forces of magnitude and frequency is mentioned and also the limitations of the method. The permissible amount of engine unbalance is the subject of current research and particulars of a ship in which troubles were experienced and overcome are given. In multi-engined ships a difference in speeds causes the phenomenon of beats, which can be avoided by making arrangements for keeping the engines in step.

The varying turning effort in reciprocating engines causes transverse vibration about the base, and when synchronisation occurs with certain harmonic components the effect will be felt in those parts of the ship having the same frequency. This is termed "tuning fork" vibration and can be alleviated in twin-screw ships by fitting ties between the engines, but the fitting of ties between the engine and casing sides in single-engined ships is not recommended. Details of an example of this problem are given for a particular ship.

Although propellers are now statically balanced and finished all over, wake variation and hydrodynamic pressure fluctuation on the hull close to the screw can set up exciting impulses at blade frequency. With reference to propeller shaft failures in certain ships one authority believes that the cause is local lateral whirling of the propeller on the overhanging shaft. The question of airborne and structure-borne noise is briefly reviewed and the paper concludes with a note on future trends.

B.B.C. Temporary Transmitter at Barnstaple

To improve reception of the Home Service programmes in certain areas, the B.B.C. is building a new low-power transmitting station at Fremington, between Barnstaple and Bideford, Devon. However, as the building and installation will take a considerable time to complete, a temporary transmitter installed in a caravan is being used on the site so that listeners in this area may have an improved service much earlier than would otherwise have been possible. The caravan transmitter was brought into service on March 9th, with a wavelength of 285m (1052kc/s) and will radiate the West of England Home Service. The aerial system already erected for the permanent station is being used for the temporary transmitter.

The station is intended to serve Barnstaple, Bideford and their immediate surroundings, but maximum coverage of the outlying areas will not be achieved until the permanent station is in operation. The temporary transmitting equipment consists of two 250W medium-wave transmitters, one normally being a reserve for use in the event of a breakdown, but provision is being made for paralleling the two outputs to give a total aerial power of 500W.

The programme will be fed to the transmitter over Post Office circuits. Four G.P.O. lines are terminated in the vehicle—a programme line and a spare programme line, a control line to the nearest B.B.C. centre and a G.P.O. telephone circuit. Power for the transmitter is obtained from a British Electricity Authority supply cable terminated on the site in a small kiosk, which houses the main fuses, metering equipment and main switch, and is provided with an outlet socket to take a special heavy-duty watertight plug, to which is connected the main cable feeding the caravan.

The forward end of the caravan forms the "transmitter hall." In this part are lockers which house the monitoring equipment, re-broadcast receiver, spares and test equipment. A collapsible writing table and a work-bench with two cupboards underneath are also provided. The transmitters, which face forward, form the rear boundary of this section and are mounted one on each side of the caravan. The space between them gives access to a "corridor," whose sides are formed by the crystal drive which maintains the transmitter exactly on its allotted wavelength, and the programme amplifiers and test equipment. At the rear end are fitted an electric cooker, a sink unit and an electric water heater. Provision is made for connection to the mains water supply, but should this not be available water is drawn from the storage tank provided. Space has been left for the future installation of remote control gear, which would enable the transmitter to work unattended. It would then be remotely operated over a Post Office telephone circuit from the nearest permanent B.B.C. establishment.

A standard four-berth caravan, measuring approximately 7ft wide and 20ft long, mounted on a specially strengthened chassis and with its interior arrangement modified to B.B.C. design, has been used. The vehicle is electrically heated, the distribution fan of the system being capable of independent operation for cold air circulation, if required in the summer. Additional extract fans are provided to discharge waste heat from the transmitters through louvres in the side of the vehicle in hot weather.

Technical Reports

An Improved Harmonic Analyser and Noise-meter (Report Ref. M/T108). The British Electrical and Allied Industries Research Association. Price 3s., postage 3d.—An instrument is described which has been developed to overcome some of the disadvantages associated with earlier instruments especially when employed for measurements on systems where the fundamental frequency and load are fluctuating. It should be said that the use is now envisaged of equipment designed on entirely different principles which has many advantages over the instrument which is the subject of the present report.

Intrinsically Safe Electrical Apparatus : Relation of Igniting Current to Circuit Inductance for Inflammable Mixtures with Air of Carbon Monoxide, Coal Gas and Hydrogen (Report Ref. G/T257). By E. M. Guenault, M.Sc., Ph.D., and E. Atherton. The British Electrical and Allied Industries Research Association. Price 7s. 6d., postage 3d.—The report deals with the determination of the range of mixture with air of carbon monoxide, "enriched" coal gas and hydrogen most readily ignited by the sparks produced by the rapid interruption of an inductive circuit operated at 24V d.c., and with the relation of igniting currents to circuit inductance for such mixtures. Under the conditions of test it is found that such mixtures of these gases are more readily ignited than a mixture of methane and air containing 8·3 per cent methane. The coal gas and hydrogen mixtures in particular have igniting currents substantially lower than the most readily ignited mixture of methane and air.

THE ENGINEER

Vol. CXCIII MARCH 14, 1952 No. 5016

Contents

PAGE

LEADING ARTICLES—
An Encouraging Budget ... 376
Prestressed Concrete Economics ... 376

SPECIAL ARTICLES—
Cross-Channel Steamer "Normannia." No. II. (Illus.) ... 362
Flow of Wet Steam. No. II. (Illus.) ... 363
Quincentenary of Leonardo da Vinci. (Illus.) ... 378

B.B.C: Temporary Transmitter at Barnstaple ... 375
Bristol "Britannia" Air Liner. (Illus.) ... 367
Conducting Coatings on Glass ... 367
Epicyclic Gears. No. I. (Illus.) ... 373
Gear Tooth Stresses and Rating Formulæ. No. II. (Illus.) ... 384
Heavy Fuels for Diesel Engines: Institution of Mechanical Engineers ... 380
Kirk o' Shotts Television Transmitting Station. (Illus.) ... 371
Rolling Lift Bridge at Surrey Docks. (Illus.) ... 383
Sindri Fertiliser Factory. No. II. (Illus.) ... 368
Vibrations in Marine Engineering ... 375
Water Intake at Coryton Refinery. (Illus.) ... 382

PAGE

LETTERS TO THE EDITOR—
Garratt and the Gas Turbine ... 377
"Phenomenological" ... 377

LITERATURE—
Short Notices ... 377

A SEVEN-DAY JOURNAL ... 361
A Film on Harbour Construction in West Africa
National Coal Board's Awards to Inventors
Report on the Monopolies and Restrictive Practices Act
The Budget
The Late Mr. W. H. Pilmour
The Professional Engineers' Appointment Bureau

NEWS AND NOTES—
American Engineering News. (Illus.) ... 387
British Patent Specifications. (Illus.) ... 391
Contracts ... 390
Forthcoming Engagements ... 392
Industrial and Labour Notes ... 389
Launches and Trial Trips ... 392
Notes and Memoranda ... 390
Personal and Business ... 390
Technical Reports ... 375

AN ENCOURAGING BUDGET

THE Budget that Mr. Butler presented to the House of Commons last Tuesday afternoon proved to be not only less severe than had generally been feared, but more encouraging than anyone had imagined it was likely to be. Indeed, it broke right away from the character of all Budgets presented since the end of the war. For, quite clearly, an attempt has been begun to reorganise the nation's finances upon a different conception, one that in Mr. Butler's words will provide not only "a true and lasting solution for our present troubles, . . . through harder work and increased output," but, in addition, "a new spirit of satisfaction in rewards well earned." There was less emphasis upon austerity, more emphasis upon incentive. The details of the changes in the Budget are summarised elsewhere in this issue. Only its main points need mention here. They are a large and politically courageous cut in the food subsidies, against which must be placed increased family allowances, pensions, &c., together with a reduction of income tax benefiting almost the whole population; an alteration of the income tax structure in a way designed to encourage harder work as well as to benefit particularly those earning smaller incomes; an increase in the duties on oil fuels; the imposition of an excess profits levy (against which can be set a reduction in profits tax) and welcome changes in purchase tax. To accompany the Budget the Bank Rate has been raised to 4 per cent.

Much study must be given to a Budget so different in character from other post-war Budgets before any final judgment can be formed about it. Like the Federation of British Industries, which was approached by the Press as soon as the terms of the Budget were known, we feel that "snap judgments would be foolish." However, certain points are immediately obvious. For instance, the oversea unbalance of the U.K. is to be met in the only two ways in which it can be met. There is to be a further cut of about £100 million in the annual import bill on the top of the heavy cuts previously announced. Exports are to be encouraged to rise by £50 million despite impediments to trade such as the restrictions on imports already announced by Australia. Were imports to be so reduced and exports increased without other action being taken there would have been a need to increase taxation at home to prevent inflation. That need would have been further reinforced by the diversion of manufacturing capacity to the making of armaments. According to Mr. Butler's figures, the reduction of imports and increase of exports must lead to a reduction in home resources of some £200 million, whilst the diversion of resources to armament production must lead to a further reduction of £200 million, making £400 million in all. Upon the other side of the account, Mr. Butler has reckoned upon some increase of output during the current year and has brought about a reduction of some £50 million in Government expenditure. The rest—to make a balancing total of £400 million—is to be saved by "decisive steps to reduce home investment substantially." Those decisive steps consist partly of direct controls through the allocation of steel, &c., but mainly of raising the Bank Rate, thereby discouraging the creation of credit to finance investment. By those means the demand for home production upon industry in general and more particularly the metal-using industries, is to be reduced and thereby export business expedited. In effect, what is proposed is that the flow of consumption goods to the home market shall be unchecked so that increased taxation to combat inflation will be unnecessary. But, because the rate of investment at home is to be checked, benefits that might have been expected through increased production in the future are to be sacrificed to maintain standards of living now. Whether that action will prove to be wise only the future can show. One further matter merits attention here. Mr. Butler excused the raising of duties on oils by remarking that he must "pay particular attention to a scarce product which costs us foreign exchange." Yet that fact cannot conceal that a tax on fuel is a tax on a basic industry, the costs of whose services enter into almost all other products.

But if some doubts can be thus expressed about the wisdom of some of the measures proposed in the Budget, if the re-imposition of an excess profits tax is unwelcome to industry, if the cutting of home investment can only be regarded with disquietude, if the further taxation of road transport seems both inequitable and undesirable, yet the general policy that is basic to this Budget can be welcomed. It is to bring a greater rationality to bear upon the nation's finances, to make clear to the people of this country what are the real costs of what they consume and to provide better incentives to them to gain benefits by working harder. Nor should this single Budget, introduced at a time of financial stringency, be taken alone. It is clearly intended to be the first of a series imbued with a similar policy. There are further subsidies and doles, concealing true costs, from the people that can be reduced or eliminated in the future; there are further incentives to harder work to be provided by increasing earned income allowances for income tax purposes and in other ways. The excess profits levy, though imposed for an indefinite period, is not to be permanent. The Budget, indeed, holds out encouraging prospects for the future. Combined with the determination of the Commonwealth to make sterling oversea accounts show a surplus by the end of the year and to work for early convertibility of sterling and the dollar, it suggests, more than any Budget introduced since the war, an abounding confidence in the ability of this country to get away from a situation when each alternate year there is a financial crisis.

PRESTRESSED CONCRETE ECONOMICS

CONSTRUCTION in prestressed concrete has spread rapidly in this country during the past two or three years, despite the restricted amount of work which has been in progress. Precast prestressed structural elements are now being widely used, and the demand for them is increasing, as is shown by the fact that the twenty-six firms in this country which manufacture such elements are planning to increase their joint stress bed capacity by 58 per cent during the course of this year. And the use of in-situ prestressed concrete has also become common, many examples of such work having been built in the past year or two, as reference to technical papers and periodicals will exemplify. Although ideas and methods were at first "imported" from the Continent, several notable advances in prestressed concrete technique have now been made here, as experience has been built up. But all the problems arising from its use are by no means solved. The discussion entitled "Relative Economics of Prestressed Concrete Compared with Other Forms of Construction—Aluminium, Reinforced Concrete, Steel and Timber," which was held at the Institution of Civil Engineers on Thursday, February 28th, drew attention to a number of these points. The discussion was introduced by short notes on each of the various structural materials mentioned in the title, each prepared by an authority on that material, and a lively debate ensued.

The discussion, it seemed, could be divided into two parts, the first concerning the

economic advantages of prestressed concrete compared with the other materials, and the second, which arose from it, challenging the technical soundness of design in this medium. Some doubts were expressed about the high stresses used for the steel wires, for instance, and about the sparsity of knowledge about creep and corrosion of the steel over long periods. Another subject about which information was considered meagre was the resistance of prestressed concrete to fire, and also to the effects of blast. Generally, however, it seemed that prestressed concrete design was fairly well justified, and compared favourably with the long-established practices of normal reinforced concrete design. But in comparing these two materials it was pointed out that existing regulations governing reinforced concrete practice sometimes put that material at a disadvantage with prestressed concrete, although the high standard of concrete quality, which was essential for prestressed work, was of general benefit to concrete construction generally. In fact, it was suggested that if a completely reliable high quality concrete could be obtained, the number of its applications could be substantially increased.

Turning now to the economic aspects of design, many points were put forward by various speakers in favour of the different materials considered, each of which in turn, it was claimed, showed savings in first cost, maintenance costs, erection, and so on. In defence of steel construction it was stated that, for buildings, prestressed concrete appeared to have little chance of competing economically with steel, whilst for bridges it was conceded that prestressed concrete should be advantageous in spans of 50ft or less, the advantage becoming progressively less for spans from 50ft to 200ft or 250ft, with structural steel the master for longer spans. As regards multi-storey buildings, however, other speakers pointed out that where the L.C.C. regulations applied (i.e., where structural steel must be encased in concrete for fire protection), a reinforced concrete frame showed an appreciable saving over structural steel, which was thought acceptable economically in such circumstances only if the construction time were a paramount consideration. Perhaps the most valuable comparison, however, was the series of costs given by one speaker from his experience, for a 24ft span beam with a loading of 1300 lb per foot run. The costs were, for reinforced concrete, 19s. to 24s. 6d. per foot run of beam; for prestressed concrete 19s. to 25s. per foot run; and for steel 49s. 3d. to 53s. 9d. per foot run. In the case of a 45ft span beam with a load of 1600 lb per foot run, the corresponding figures for the three materials were, respectively, 32s. to 41s. 6d., 35s. to 44s., and 63s. to 71s. For columns the position was similar, but for roofing, steel was generally cheaper for the longer spans and lighter loading, with, of course, the proviso that it had not to be encased. But many factors must be taken into account in considering such figures of comparative costs, and there are many instances in which the various materials considered in the discussion are complementary, each with its own undisputed sphere of use. Nevertheless, there remains a field over which they are competitive and where it is not always clear where the advantage lies. Some of the speakers in the discussion were frankly "partisan," in favour of the material with which they were most accustomed to work, and it is probable that a thorough knowledge and experience of one structural material will enable a designer to use it, and use it effectively, when a second designer with different experience would reject it as unsuitable. Again, factors such as the availability of trained labour, or of plant, the experience of contractors, shortages of materials (the steel shortage was a prominent point in the discussion), and speed of erection exert an influence on the designer's choice. It was perhaps such points as these which led the principal speaker on prestressed concrete to remark that "prestressed concrete scores well in the drawing office." For when considering all these factors, it becomes very difficult to make a precise comparison between the costs of different structures or to say with certainty that a structure is the most economical one in a given case. One method of obtaining such knowledge is by permitting tenderers to submit alternative designs to the "official design" for a project. As an example, there can be little doubt that the Vila Franca bridge, which was described in these columns on December 21st last, was the most economical structure which could have been erected for its purpose. In asking for tenders, an official design was given but tenderers were asked to submit alternative designs if they could do so to advantage. In this particular case the official design proved to be a costly one. Undoubtedly this method has its limitations, but it is successfully used on the Continent. Prestressed concrete structures have been shown to be advantageous in a number of instances where it has been used (the bridge at Sclayn in Belgium is one example). Whether they would show similar advantage in this country, were such a system employed, appears to be probable but not certain. For although such direct comparison is lacking, many studies of costs must have been made in design offices before the adoption of the various prestressed concrete structures which have been erected in this country during the past two years or so. The steel shortage has been, and still is, a potent factor in encouraging prestressed concrete, but it seems that, apart from any such stimulus, this material will continue to play an increasingly important part in structural engineering.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

"PHENOMENOLOGICAL"

SIR,—I was very interested to read in your February 29th issue a criticism of my use of the word "phenomenological" and your admirable defence of it, to which little further could be added.

To my understanding, the word describes a precise scientific method which is often confused with the *ad hoc* method, to which, although quite different, it bears a superficial resemblance. Their starting points are the same, namely, a set of experimental data unco-ordinated by fundamental theory; their immediate procedures are the same, namely, a fitting of mathematical formulæ to the data; but their techniques differ as widely as their objectives, which are, of the phenomenological method, to determine first principles of wide application, and of the *ad hoc* method, to draw immediate limited conclusions for some practical end. The only consideration of the latter is to represent the immediate data as accurately as both they allow and the particular application requires, and convenience is the only limitation and guide. If the chosen formula is poor and so-called constants vary, any arbitrary improvements may be at once introduced. For the former, economy of hypothesis as expressed by use of the smallest number of adjustable constants is the limitation, and guidance is provided *a priori* by such long-range considerations as the investigator may have in mind. Assumptions are explicitly made and compared with the widest range of fact; they are not rejected, even though agreement is poor, until the accumulated evidence against them shows clearly how they should be changed.

I do not know whether use of the word "phenomenological" in this connection will commend itself to your readers, but it is the meaning I assumed when using it in my title.

A. GRAHAM

Leicester, March 4th.

THE GARRATT AND THE GAS TURBINE

SIR,—I refer to Mr. Livesay's letter in your issue of February 15, 1952. I am so ignorant of locomotives that I do not really appreciate all that is implied by the style "Garratt." It is that ignorance which entitles me to ask you what is meant by your correspondent's last few phrases: "I had better try and transfer my affections to it (the gas turbine). I shall try, but—!"

I cannot help wondering if Mr. Livesay (who by his letter is self-proved to be a flier of kites or a trailer of coat-tails) means that he is in doubt about the applicability of gas turbines to locomotives. There should, to such an intelligence as his, be no question about it. Gas turbines are going to be the best prime movers for locomotives, by any reasonable economic or technical criteria. The operative words are "going to be." Let me anticipate criticism of that phrase by pointing out that gas turbines are the only systems in relation to which acceptable accurate predictions can be made before test and adoption. This has been demonstrated repeatedly.

Moreover, gas turbine systems in one form or another (chiefly another—the turbo-supercharger) are perhaps one of the most reliable and maintainable pieces of equipment in the whole field of power production.

W. E. P. JOHNSON

London, W.1,
February 28th.

SHORT NOTICES

Patents, Designs and Trade Marks. By Charles S. Parsons. Technical Press, Ltd., Gloucester Road, Kingston Hill, Surrey. Price 14s.—This book, first published in 1938, has been re-issued with a supplement referring to the changes in patent and design law which were effected in 1949.

The book is written primarily for the information of manufacturers and traders, and is in no sense a legal textbook. Much of the information contained in it is of general import and is independent of the 1949 changes. The supplement serves a useful purpose in bringing the book up to date, although many readers may find difficulty in marrying the supplement with the main text. It might have been better, indeed, to sacrifice many of the references in the supplement in favour of more general statements emphasising the practical effects and implications of the major alterations of the law. However, the main purpose of the book, in its new form, remains unaffected.

THE ENGINEER

Vol. CXCIII MARCH 14, 1952 No. 5016

Contents

PAGE

LEADING ARTICLES—
An Encouraging Budget ... 376
Prestressed Concrete Economics ... 376

SPECIAL ARTICLES—
Cross-Channel Steamer "Normannia." No. II. (Illus.) ... 362
Flow of Wet Steam. No. II. (Illus.) ... 363
Quincentenary of Leonardo da Vinci. (Illus.) ... 378

B.B.C. Temporary Transmitter at Barnstaple ... 375
Bristol "Britannia" Air Liner. (Illus.) ... 367
Conducting Coatings on Glass ... 367
Epicyclic Gears. No. I. (Illus.) ... 373
Gear Tooth Stresses and Rating Formulæ. No. II. (Illus.) ... 384
Heavy Fuels for Diesel Engines: Institution of Mechanical Engineers ... 380
Kirk o' Shotts Television Transmitting Station. (Illus.) ... 371
Rolling Lift Bridge at Surrey Docks. (Illus.) ... 383
Sindri Fertiliser Factory. No. II. (Illus.) ... 368
Vibrations in Marine Engineering ... 375
Water Intake at Coryton Refinery. (Illus.) ... 382

PAGE

LETTERS TO THE EDITOR—
Garratt and the Gas Turbine ... 377
"Phenomenological" ... 377

LITERATURE—
Short Notices ... 377

A SEVEN-DAY JOURNAL ... 361
A Film on Harbour Construction in West Africa
National Coal Board's Awards to Inventors
Report on the Monopolies and Restrictive Practices Act
The Budget
The Late Mr. W. H. Pilmour
The Professional Engineers' Appointment Bureau

NEWS AND NOTES—
American Engineering News. (Illus.) ... 387
British Patent Specifications. (Illus.) ... 391
Contracts ... 390
Forthcoming Engagements ... 392
Industrial and Labour Notes ... 389
Launches and Trial Trips ... 392
Notes and Memoranda ... 390
Personal and Business ... 390
Technical Reports ... 375

AN ENCOURAGING BUDGET

THE Budget that Mr. Butler presented to the House of Commons last Tuesday afternoon proved to be not only less severe than had generally been feared, but more encouraging than anyone had imagined it was likely to be. Indeed, it broke right away from the character of all Budgets presented since the end of the war. For, quite clearly, an attempt has been begun to reorganise the nation's finances upon a different conception, one that in Mr. Butler's words will provide not only "a true and lasting solution for our present troubles, . . . through harder work and increased output," but, in addition, "a new spirit of satisfaction in rewards well earned." There was less emphasis upon austerity, more emphasis upon incentive. The details of the changes in the Budget are summarised elsewhere in this issue. Only its main points need mention here. They are a large and politically courageous cut in the food subsidies, against which must be placed increased family allowances, pensions, &c., together with a reduction of income tax benefiting almost the whole population; an alteration of the income tax structure in a way designed to encourage harder work as well as to benefit particularly those earning smaller incomes; an increase in the duties on oil fuels; the imposition of an excess profits levy (against which can be set a reduction in profits tax) and welcome changes in purchase tax. To accompany the Budget the Bank Rate has been raised to 4 per cent.

Much study must be given to a Budget so different in character from other post-war Budgets before any final judgment can be formed about it. Like the Federation of British Industries, which was approached by the Press as soon as the terms of the Budget were known, we feel that "snap judgments would be foolish." However, certain points are immediately obvious. For instance, the oversea unbalance of the U.K. is to be met in the only two ways in which it can be met. There is to be a further cut of about £100 million in the annual import bill on the top of the heavy cuts previously announced. Exports are to be encouraged to rise by £50 million despite impediments to trade such as the restrictions on imports already announced by Australia. Were imports to be so reduced and exports increased without other action being taken there would have been a need to increase taxation at home to prevent inflation. That need would have been further reinforced by the diversion of manufacturing capacity to the making of armaments. According to Mr. Butler's figures, the reduction of imports and increase of exports must lead to a reduction in home resources of some £200 million, whilst the diversion of resources to armament production must lead to a further reduction of £200 million, making £400 million in all. Upon the other side of the account, Mr. Butler has reckoned upon some increase of output during the current year and has brought about a reduction of some £50 million in Government expenditure. The rest—to make a balancing total of £400 million—is to be saved by "decisive steps to reduce home investment substantially." Those decisive steps consist partly of direct controls through the allocation of steel, &c., but mainly of raising the Bank Rate, thereby discouraging the creation of credit to finance investment. By those means the demand for home production upon industry in general and more particularly the metal-using industries, is to be reduced and thereby export business expedited. In effect, what is proposed is that the flow of consumption goods to the home market shall be unchecked so that increased taxation to combat inflation will be unnecessary. But, because the rate of investment at home is to be checked, benefits that might have been expected through increased production in the future are to be sacrificed to maintain standards of living now. Whether that action will prove to be wise only the future can show. One further matter merits attention here. Mr. Butler excused the raising of duties on oils by remarking that he must "pay particular attention to a scarce product which costs us foreign exchange." Yet that fact cannot conceal that a tax on fuel is a tax on a basic industry, the costs of whose services enter into almost all other products.

But if some doubts can be thus expressed about the wisdom of some of the measures proposed in the Budget, if the re-imposition of an excess profits tax is unwelcome to industry, if the cutting of home investment can only be regarded with disquietude, if the further taxation of road transport seems both inequitable and undesirable, yet the general policy that is basic to this Budget can be welcomed. It is to bring a greater rationality to bear upon the nation's finances, to make clear to the people of this country what are the real costs of what they consume and to provide better incentives to them to gain benefits by working harder. Nor should this single Budget, introduced at a time of financial stringency, be taken alone. It is clearly intended to be the first of a series imbued with a similar policy. There are further subsidies and doles, concealing true costs, from the people that can be reduced or eliminated in the future; there are further incentives to harder work to be provided by increasing earned income allowances for income tax purposes and in other ways. The excess profits levy, though imposed for an indefinite period, is not to be permanent. The Budget, indeed, holds out encouraging prospects for the future. Combined with the determination of the Commonwealth to make sterling oversea accounts show a surplus by the end of the year and to work for early convertibility of sterling and the dollar, it suggests, more than any Budget introduced since the war, an abounding confidence in the ability of this country to get away from a situation when each alternate year there is a financial crisis.

PRESTRESSED CONCRETE ECONOMICS

CONSTRUCTION in prestressed concrete has spread rapidly in this country during the past two or three years, despite the restricted amount of work which has been in progress. Precast prestressed structural elements are now being widely used, and the demand for them is increasing, as is shown by the fact that the twenty-six firms in this country which manufacture such elements are planning to increase their joint stress bed capacity by 58 per cent during the course of this year. And the use of in-situ prestressed concrete has also become common, many examples of such work having been built in the past year or two, as reference to technical papers and periodicals will exemplify. Although ideas and methods were at first "imported" from the Continent, several notable advances in prestressed concrete technique have now been made here, as experience has been built up. But all the problems arising from its use are by no means solved. The discussion entitled "Relative Economics of Prestressed Concrete Compared with Other Forms of Construction—Aluminium, Reinforced Concrete, Steel and Timber," which was held at the Institution of Civil Engineers on Thursday, February 28th, drew attention to a number of these points. The discussion was introduced by short notes on each of the various structural materials mentioned in the title, each prepared by an authority on that material, and a lively debate ensued.

The discussion, it seemed, could be divided into two parts, the first concerning the

economic advantages of prestressed concrete compared with the other materials, and the second, which arose from it, challenging the technical soundness of design in this medium. Some doubts were expressed about the high stresses used for the steel wires, for instance, and about the sparsity of knowledge about creep and corrosion of the steel over long periods. Another subject about which information was considered meagre was the resistance of prestressed concrete to fire, and also to the effects of blast. Generally, however, it seemed that prestressed concrete design was fairly well justified, and compared favourably with the long-established practices of normal reinforced concrete design. But in comparing these two materials it was pointed out that existing regulations governing reinforced concrete practice sometimes put that material at a disadvantage with prestressed concrete, although the high standard of concrete quality, which was essential for prestressed work, was of general benefit to concrete construction generally. In fact, it was suggested that if a completely reliable high quality concrete could be obtained, the number of its applications could be substantially increased.

Turning now to the economic aspects of design, many points were put forward by various speakers in favour of the different materials considered, each of which in turn, it was claimed, showed savings in first cost, maintenance costs, erection, and so on. In defence of steel construction it was stated that, for buildings, prestressed concrete appeared to have little chance of competing economically with steel, whilst for bridges it was conceded that prestressed concrete should be advantageous in spans of 50ft or less, the advantage becoming progressively less for spans from 50ft to 200ft or 250ft, with structural steel the master for longer spans. As regards multi-storey buildings, however, other speakers pointed out that where the L.C.C. regulations applied (i.e., where structural steel must be encased in concrete for fire protection), a reinforced concrete frame showed an appreciable saving over structural steel, which was thought acceptable economically in such circumstances only if the construction time were a paramount consideration. Perhaps the most valuable comparison, however, was the series of costs given by one speaker from his experience, for a 24ft span beam with a loading of 1300 lb per foot run. The costs were, for reinforced concrete, 19s. to 24s. 6d. per foot run of beam; for prestressed concrete 19s. to 25s. per foot run; and for steel 49s. 3d. to 53s. 9d. per foot run. In the case of a 45ft span beam with a load of 1600 lb per foot run, the corresponding figures for the three materials were, respectively, 32s. to 41s. 6d., 35s. to 44s., and 63s. to 71s. For columns the position was similar, but for roofing, steel was generally cheaper for the longer spans and lighter loading, with, of course, the proviso that it had not to be encased. But many factors must be taken into account in considering such figures of comparative costs, and there are many instances in which the various materials considered in the discussion are complementary, each with its own undisputed sphere of use. Nevertheless, there remains a field over which they are competitive and where it is not always clear where the advantage lies. Some of the speakers in the discussion were frankly "partisan," in favour of the material with which they were most accustomed to work, and it is probable that a thorough knowledge and experience of one structural material will enable a designer to use it, and use it effectively, when a second designer with different experience would reject it as unsuitable. Again, factors such as the availability of trained labour, or of plant, the experience of contractors, shortages of materials (the steel shortage was a prominent point in the discussion), and speed of erection exert an influence on the designer's choice. It was perhaps such points as these which led the principal speaker on prestressed concrete to remark that "prestressed concrete scores well in the drawing office." For when considering all these factors, it becomes very difficult to make a precise comparison between the costs of different structures or to say with certainty that a structure is the most economical one in a given case. One method of obtaining such knowledge is by permitting tenderers to submit alternative designs to the "official design" for a project. As an example, there can be little doubt that the Vila Franca bridge, which was described in these columns on December 21st last, was the most economical structure which could have been erected for its purpose. In asking for tenders, an official design was given but tenderers were asked to submit alternative designs if they could do so to advantage. In this particular case the official design proved to be a costly one. Undoubtedly this method has its limitations, but it is successfully used on the Continent. Prestressed concrete structures have been shown to be advantageous in a number of instances where it has been used (the bridge at Sclayn in Belgium is one example). Whether they would show similar advantage in this country, were such a system employed, appears to be probable but not certain. For although such direct comparison is lacking, many studies of costs must have been made in design offices before the adoption of the various prestressed concrete structures which have been erected in this country during the past two years or so. The steel shortage has been, and still is, a potent factor in encouraging prestressed concrete, but it seems that, apart from any such stimulus, this material will continue to play an increasingly important part in structural engineering.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

"PHENOMENOLOGICAL"

SIR,—I was very interested to read in your February 29th issue a criticism of my use of the word "phenomenological" and your admirable defence of it, to which little further could be added.

To my understanding, the word describes a precise scientific method which is often confused with the *ad hoc* method, to which, although quite different, it bears a superficial resemblance. Their starting points are the same, namely, a set of experimental data unco-ordinated by fundamental theory; their immediate procedures are the same, namely, a fitting of mathematical formulæ to the data; but their techniques differ as widely as their objectives, which are, of the phenomenological method, to determine first principles of wide application, and of the *ad hoc* method, to draw immediate limited conclusions for some practical end. The only consideration of the latter is to represent the immediate data as accurately as both they allow and the particular application requires, and convenience is the only limitation and guide. If the chosen formula is poor and so-called constants vary, any arbitrary improvements may be at once introduced. For the former, economy of hypothesis as expressed by use of the smallest number of adjustable constants is the limitation, and guidance is provided *a priori* by such long-range considerations as the investigator may have in mind. Assumptions are explicitly made and compared with the widest range of fact; they are not rejected, even though agreement is poor, until the accumulated evidence against them shows clearly how they should be changed.

I do not know whether use of the word "phenomenological" in this connection will commend itself to your readers, but it is the meaning I assumed when using it in my title.

A. GRAHAM

Leicester, March 4th.

THE GARRATT AND THE GAS TURBINE

SIR,—I refer to Mr. Livesay's letter in your issue of February 15, 1952. I am so ignorant of locomotives that I do not really appreciate all that is implied by the style "Garratt." It is that ignorance which entitles me to ask you what is meant by your correspondent's last few phrases: "I had better try and transfer my affections to it (the gas turbine). I shall try, but—!"

I cannot help wondering if Mr. Livesay (who by his letter is self-proved to be a flier of kites or a trailer of coat-tails) means that he is in doubt about the applicability of gas turbines to locomotives. There should, to such an intelligence as his, be no question about it. Gas turbines are going to be the best prime movers for locomotives, by any reasonable economic or technical criteria. The operative words are "going to be." Let me anticipate criticism of that phrase by pointing out that gas turbines are the only systems in relation to which acceptable accurate predictions can be made before test and adoption. This has been demonstrated repeatedly.

Moreover, gas turbine systems in one form or another (chiefly another—the turbo-supercharger) are perhaps one of the most reliable and maintainable pieces of equipment in the whole field of power production.

W. E. P. JOHNSON

London, W.1,
February 28th.

SHORT NOTICES

Patents, Designs and Trade Marks. By Charles S. Parsons. Technical Press, Ltd., Gloucester Road, Kingston Hill, Surrey. Price 14s.—This book, first published in 1938, has been re-issued with a supplement referring to the changes in patent and design law which were effected in 1949.

The book is written primarily for the information of manufacturers and traders, and is in no sense a legal textbook. Much of the information contained in it is of general import and is independent of the 1949 changes. The supplement serves a useful purpose in bringing the book up to date, although many readers may find difficulty in marrying the supplement with the main text. It might have been better, indeed, to sacrifice many of the references in the supplement in favour of more general statements emphasising the practical effects and implications of the major alterations of the law. However, the main purpose of the book, in its new form, remains unaffected.

Quincentenary of Leonardo da Vinci

Leonardo da Vinci was born in 1452 *and died in* 1519. *In honour of his quincentenary an exhibition is being held at the Royal Academy, at which a large number of his drawings are on show. Comments are here made upon that part of the exhibition that is concerned with Leonardo's work as a scientist and engineer; and upon his character as revealed by his own drawings and writings in the exhibition. The exhibition reveals the great wealth of his talents and his astonishing perception in scientific and mechanical subjects.*

FIVE hundred years ago, on April 15, 1452, there came into the world in the Tuscan village of Vinci one of the most remarkable men who has ever lived. In the latter half of the fifteenth century the Renaissance in Italy had progressed so far that men's minds were already freeing themselves from implicit belief in the infallibility of ancient authorities and the truth of traditional teaching. The way was opening for men to think, to write, and to speak freely and to inquire curiously into the "why" and "how" of what went on in the world. Thus the time was ripe for such an intelligence as that of Leonardo da Vinci to flourish. To his active mind there was presented an enormous wealth of problems awaiting solution. An exhibition, opened at the Royal Academy, London, last Thursday, March 6th, shows not only what great contributions Leonardo made towards the solution of those problems, but also, through the evidence of his own paintings, drawings and writings, what sort of a man he was and over what an enormous range of subjects his mind roved, questing for an extension of his knowledge.

We know that Leonardo was a great painter. For at the very beginning of the sixteenth century and before a constellation of new personalities, including Michelangelo and Raphael arose in Florence, he was

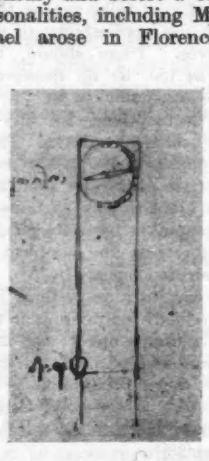


FIG. 1—THE MAGNETIC NEEDLE

A compass is mounted in a frame with two spiked feet to be stuck in the ground. A plumb-line ensures verticality. This is the first known apparatus for observing magnetic dip.

acknowledged as the greatest artist in Italy. But just how great he was as an artist it is difficult for us to judge from the very few paintings, undoubtedly from his hand, that have come down to us undamaged by time or the efforts of restorers. For in all things, not excluding painting and drawing, Leonardo was an experimentalist. He experimented in painting, not only with methods, but also with materials, with the result that even within his own lifetime so great a masterpiece as his "Last Supper" was beginning to decay. We have, indeed, to assess his mastery of painting as much from contemporary copies of his works, from the influence of his style on other artists, and from the wealth of his own drawings and cartoons that survive, as from the few paintings that have come down to us. Of other artistic activities hardly anything remains. None of his sculptures has survived. And in the nature of things we can know little of the fertility of invention and phantasy that he no doubt threw into the formulation and organisation of masques and pageants for the brilliant court of Ludovico Sforza at Milan, which he served from 1481

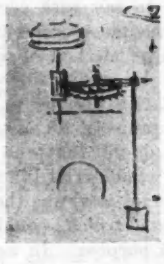


FIG. 2—CLOCK PENDULUM

This is the earliest known example of the use of a pendulum as a clock regulator.

to 1500 and where, it seems probable, his happier years were spent. But what we do know of him with much greater certainty is the extent of his engineering skill and the scientific precision and penetration of his intellect. For there have come down to us more than 5000 pages of his notebooks in which he recorded what he observed, the results of his experiments and his projects for designs. Many pages from those notebooks are reproduced at the exhibition. By the courtesy of the Science Museum, South Kensington, we are able to reproduce a few here. They prove him to have been a scientific and mechanical genius. But unfortunately, he was so far ahead of his time that men took little note in his own age of his discoveries, although his artistic eminence was immediately recognised. Not until some centuries later—not, indeed, at all fully until some seventy years ago—were his abilities as a scientist and an engineer appreciated, by which time most of his discoveries had been independently rediscovered by those who came after him.

In wandering through the exhibition at the Academy the observer becomes aware that he is in the presence of a mind that combines an almost inhumanly perceptive intelligence with the delighted curiosity of a child encountering for the first time some new and undreamed of activity. At least when he was young, life to Leonardo, whatever trials befell him, must have seemed an endless delight. Always he seems to have had by him his stylus, enthusiastically ready to depict some "caricature of a face" that took his fancy, to portray the movement of an animal, often as much to show "how" it performed the movement as because the movement was in itself æsthetically attractive, to make a meticulously detailed study of the arrangement of the muscles, the veins and the bones of a dissected body, to jot down the elements of some machine or device that caught his attention, or to make a note of some thought, artistic or scientific, brought to his mind by an event or a conversation. Nor was observation all. As likely as not, having seen, say, how muscles contrived the action of a limb, his imagination would be fired not merely to exploit a similar mechanism in a machine, but to study with precision the theory of the mechanism. Scarcely anything that came within his notice seems to have been unable to awaken his curiosity and fire his imagination. To take at random only some of those drawings at the exhibition of direct interest to engineers—thus excluding the whole fields of anatomy, architecture and art in which he was also so eminent—we find him studying the strength of beams and testing the tensile strength of wire; observing the phenomena of friction; recording observations of the movement of a magnetic needle (Fig. 1); designing anemometers and self-registering balances; applying the pendulum to the escapement of a clock (Fig. 2); laying out machinery for the construction of canals (Fig. 3); recording the design of

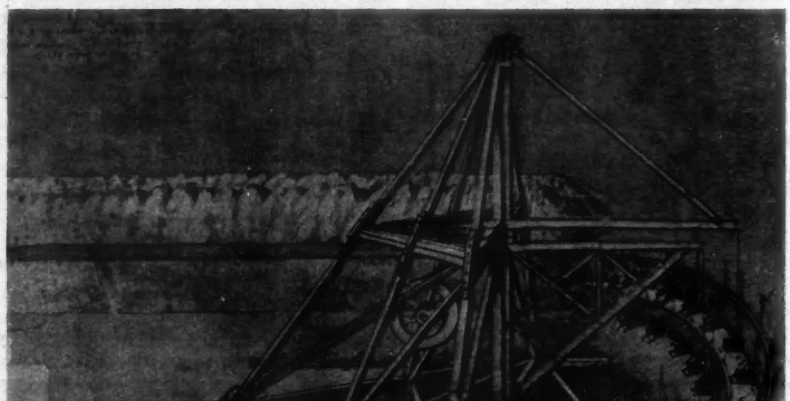


FIG. 3—EXCAVATION OF A CANAL

Excavation proceeds at two levels and the spoil is emptied by the crane on the banks. The crane can be moved forward as excavation proceeds.

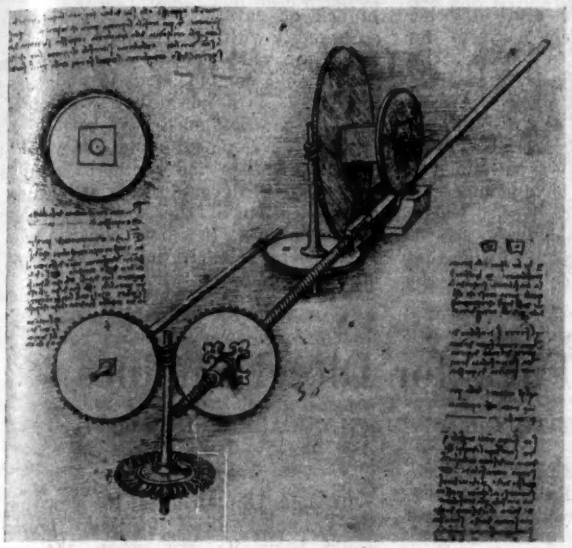


FIG. 4—ROLLING MILL

The mill is driven by water wheel through worm gearing. It is designed for the making of iron staves from which, bound and welded together, gun barrels were made. The staves being tapered to the section shown on the right, the roller was ground to spiral form.

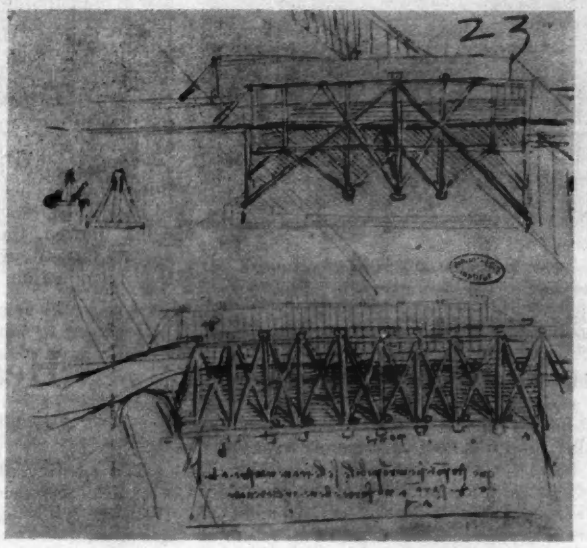


FIG. 5—DESIGNS FOR GIRDER BRIDGES

This is the earliest known illustration of Trussed girder bridges.

pumps, rolling mills (Fig. 4), and tilt hammers sometimes with improvements of his own; originating mitred lock gates (Fig. 6) and girder bridges (Fig. 5); improving textile machinery, ropewinding machinery and file cutting machinery (Fig. 7); devising means for grinding glass mirrors flat and concave; designing a treadle lathe in which the work is rotated continuously (Fig. 8) and a screw-cutting machine (Fig. 9); studying mechanics generally, including spur and helical gearing; suggesting the use of driving chains; depicting and probably originating the self-centring chuck (Fig. 10); and, upon the military side, portraying multi-barrelled guns, mortars, enormous ballistas (Fig. 11), even something remotely resembling a "tank." To that, far from exhaustive, list must be added all his studies of the flight of birds undertaken in the attempt to devise a practicable flying machine—not to speak of designs for a helicopter and parachutes. It is an astonishing collection. The pages of Leonardo's engineering notebooks would alone be sufficient to make him famous, quite apart from his equally penetrating studies in anatomy and the drawings that have delighted the artistic for centuries. Those pages are all the more astonishing in that they are the collection of a man who might well be regarded pre-eminently as one with a "grasshopper mind." For if they show, as they do, how pertinacious Leonardo could be in seeking the truth and how meticulous was his care for detail in portraying what he saw, they also provide evidence, in support of that of contemporaries, as to the ease with which his line of thought could sometimes be diverted from one track to another depending upon the way his enthusiasm was awakened. There is, for instance, one drawing containing upon a single sheet such incongruous studies as those of the head of an old man, a botanical subject and a geometrical drawing with a long marginal note. There are many others containing a like mixture of subjects. It is, indeed, typical of the man's character that though, founded upon the observations recorded in the notebooks, it is believed that he intended to write books on mechanics, the flight of birds, the elements of machinery and other subjects he never got down to doing so. For there was always so much more to investigate, so many more exciting paths to follow, so much more knowledge to pursue! What was left for posterity was, in effect, an indigestible mass of notes, a mass of material made the more indigestible, in that it was written in a "looking glass" writing easy for Leonardo, as a left-hander, to write, but difficult for those who came after to decipher. To this day we cannot fully determine from those notes (or from other sources) how much of what is noted down was originated by Leonardo and how much is only recording the work of others, observed by him. Only as late as 1797, when G. B. Venturi published an essay upon him, did his stature as a man of science begin to be appreciated. The work of publishing his notebooks in facsimile was begun only seventy years ago.

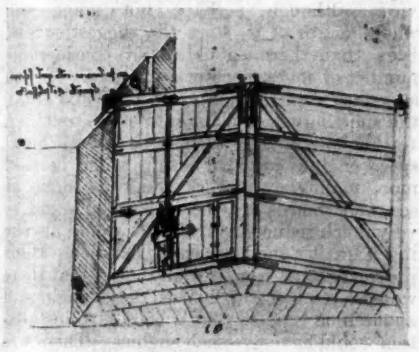


FIG. 6—CANAL LOCK GATE

Leonardo is believed to have invented mitred lock-gates.

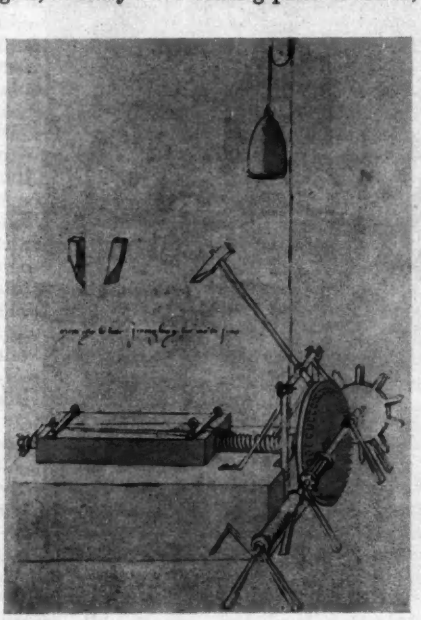


FIG. 7—FILE CUTTING MACHINE

The falling weight lifts and releases the hammer and causes the file blank holder to traverse.

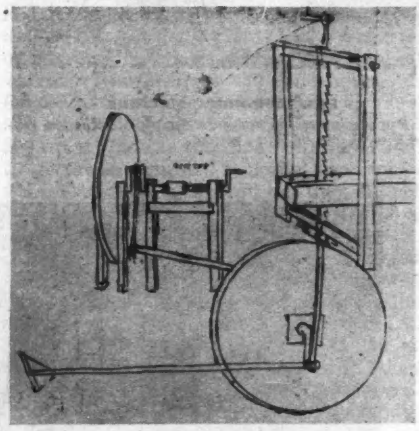


FIG. 8—LATHE AND SAW-FRAME

The earliest known representation of a lathe, in which the work rotates continuously.

In youth Leonardo seems to have been primarily the courtier and the artist, the designer of masques and pageants for a splendid court, the painter and the modeller. But from an early age he clearly took an interest in military engineering. For it is upon his skill in that field at least as much as upon his abilities as a painter and sculptor that he offered his services to Ludovico Sforza at the age of twenty-nine. Moreover, in the urge, felt by many other artists

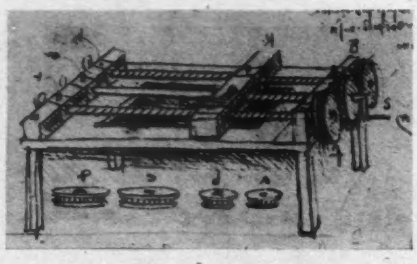


FIG. 9—SCREW-CUTTING MACHINE

The outer screwed shafts traverse a tool holder, which cuts a thread (of the opposite hand) upon the central shaft. The latter is geared to the outer shafts. Notice that change wheels are available. Similarly advanced designs are not recorded again until the eighteenth century.

besides himself to draw the human body truly, he was led, like them, to the study of anatomy. But he pursued that study far further than was necessary merely to support his desire for accuracy in art, depicting in drawings, and commenting upon, not only surface anatomy, but the arrangement of internal organs and the detailed structure of the brain, the heart, the arteries and other parts of the head, body and limbs. Those studies caused him to question the infallibility of traditional authorities and to trust rather to his own experience than to their pronouncements. Maybe he was thereby encouraged to experiment also in other fields, finding therein rich harvests for an intellect such as his to gather. Undoubtedly his scientific curiosity grew upon him, so that, looking back upon him from the present day, we see him as a man at least as great in science and in engineering as in his art. That seems to our day a phenomenon. For few men since his day have commanded so high a degree of eminence over so wide a field. Indeed, the divorce between science and art has, in our day, become so wide that the introduction to the catalogue of the exhibition can refer to his "interest in every branch of natural science . . . inter-related so *strangely* with his artistic interests." The italics are ours. Yet is it strange that a man should combine artistic and scientific interests? Is it not rather a defect of our day and one that must have harmful effects upon the development of our community that so few scientists and engineers have much artistic knowledge and so few artists any real comprehension of the works of scientists and engineers? It is not Leonardo who had a strangely balanced mind.; it is we, his unworthy followers, who are so afflicted.

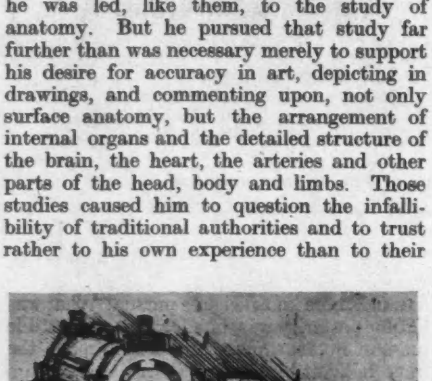


FIG. 10—BORING MACHINE

For use in making wooden water pipes. The two self-centring chucks should be noticed.

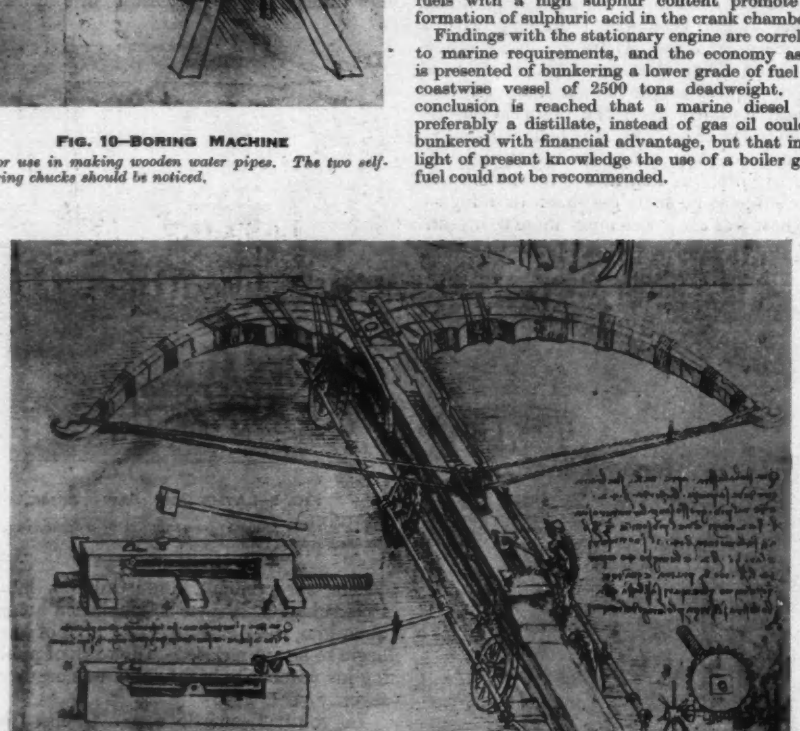


FIG. 11—BALLISTA

Loaded through the use of the windlass and gearing shown in detail on the right. Firing mechanisms are shown on the left.

Heavy Fuels for Diesel Engines

THE INSTITUTION OF MECHANICAL ENGINEERS

AT a meeting of the Institution of Mechanical Engineers, last Friday, March 7, 1952, the following paper was presented and discussed :—

THE USE OF HEAVY FUELS FOR MEDIUM-SIZED MARINE AND STATIONARY DIESEL ENGINES

By J. R. P. SMITH

Problems are discussed associated with the burning of heavy fuels in medium-speed, two-cycle, trunk-piston types of engine. Tests with a stationary engine are described, and performances, rates of cylinder bore wear, and degrees of fouling are compared, when five classes of fuel are burnt.

Pre-treatment of fuels in the centrifuge is considered, and the results from practical experience show how certain fuels with high ash content, probably in an oil-soluble form, promote rapid cylinder bore wear, even after being subjected to thorough treatment.

Comparative rates of deterioration of the lubricating oil are recorded when different classes of fuel are burnt, and figures are given which show how fuels with a high sulphur content promote the formation of sulphuric acid in the crank chamber.

Findings with the stationary engine are correlated to marine requirements, and the economy aspect is presented of bunkering a lower grade of fuel in a coastwise vessel of 2500 tons deadweight. The conclusion is reached that a marine diesel fuel, preferably a distillate, instead of gas oil could be bunkered with financial advantage, but that in the light of present knowledge the use of a boiler grade fuel could not be recommended.

DISCUSSION

Mr. John Lamb felt that the slow-running, direct-coupled diesel for ship propulsion would begin its exit when the present fantastic shipbuilding boom came to an end. He held that view because, being responsible for a great number of ships, he was very concerned, not only about the cost of repairing machinery, but the time taken to repair it, with the consequent delay to the ship. Before the war ships had usually been in berth for a matter of days, but it was now a matter of weeks, and in view of the high initial cost of ships and machinery at the present time—a cost which was three or four times that of pre-war days—all this money lying idle was a very serious matter to the shipowner. The solution to this problem might be to introduce a servicing system and to keep the ship out of service only long enough to change over the machinery. That practice had been suggested by a very distinguished member of the Institution many years ago, and though at that time he had not quite agreed with the suggestion, his experience since had led him round to that view, although perhaps not going the whole length of it, since the suggestion had been that there should be a considerable number of small machines in a ship. If such a system were to be adopted, it would entail the splitting up of plant into small units. A further advantage of having small high-speed engines to drive a ship would be that more maintenance work would be done at sea, and the cost to the shipowner would be very much reduced. The parts would also be much smaller and more easily handled. If his prophecy came true, it would mean that there would have to be high-speed diesel engines of about 1000 h.p., so that a 5000 h.p. installation would have five such engines. There was a difficulty there, since the engines could only be of a certain weight, and that weight was governed by the crane capacity of the various ship repairing establishments. In dry dock the maximum capacity ran out at about 40 tons; if the ship was afloat, much heavier weights could be lifted. His view was that they must have smaller engines which could be handled easily in a ship if they were going to make ship operation pay and stop the rising cost. In view of this, he was of the opinion that everything possible should be done to make high-speed diesel engines operative on high viscosity fuel or so-called boiler fuels.

He thought that the author made a sweeping statement when he said that, in the light of present knowledge, the use of boiler grade fuels in medium-sized engines was not justified; because his understanding was that the engines which had been tested by the

author were not adapted for burning boiler fuels and that no attempt had been made to alter, for instance, fuel nozzles or any other part which had a bearing on the proper combustion of the fuel. This had to be done in the large type marine engines, and obviously it was even more necessary in the case of small engines, not because of the constituents of the fuel, but because of the high viscosity of the fuel and the need to get the degree of penetration and atomisation necessary to ensure good combustion.

He had not had much experience with burning oil fuel on high-speed engines. The author stated that there was little information available regarding experience with trunk-piston type of two-cycle engines, and that when engines were burning boiler oil, separation of the lower end of the cylinder from the crankcase was desirable. Experience which he had himself had in the operation of two-cycle engines in which the piston skirt extended into the crankcase had caused him to be very pleased with the small amount of contamination which took place in the crankcase. Many of those engines were in service and burning high-viscosity fuels, and he had not had a single instance in which the crankcase contamination had been sufficiently great to be worrying. Of course, one could not prove in such instances whether any contamination there might be was due to mishandling or to the particular type of engine. In the only instance in which he had had experience of a high-speed engine, the engine had formed part of the propulsion installation on a voyage across the Atlantic, and for the first voyage across the Atlantic and back it had run perfectly. The performance had been just as good as that of the other three engines which were running on diesel fuel. On arrival back in this country the engine had been opened up, and certainly the inside of the cylinders had not been in the same good condition as in the case of the other engines. It had been obvious that the degree of penetration was too high and that the angle of spread had been altered to such an extent, due presumably to the higher injection pressures of the high-viscosity fuel, that the periphery of the spray had been fouling the lower end of the fuel valve housing. The experiment had not been proceeded with, because the engine had come out of the ship in order to make way for the gas turbine, but he was quite sure that if the tests had proceeded, it would have been possible to get that engine to run with no more fouling than occurred with the diesel fuel.

Mr. C. D. Brewer said that the author reviewed some of the divergent views put forward in explanation of the differences in cylinder wear observed in small and large engines. The suggestion that sulphur trioxide in the combustion chamber influenced the dewpoint had some support, but as far as was known its actual presence had never been definitely determined; nor, for that matter, had the actual condensation of aqueous acid products been established, although this theory was acceptable under certain circumstances, particularly during the warm-up period when the rate of wear was known to be very much higher than under conditions of continuous operation. Condensation might also take place during the exhaust stroke on a four-stroke engine, but experimental determination of this phenomenon presented serious practical difficulties. It was doubtful whether sulphuric acid as such was deposited on the cylinder walls, although there was reason to believe that it did form there in the lubricating oil film under favourable conditions. As regards the relative effect on cylinder wear of the first and second stages of centrifuging, it was unfortunate that no wear results were reported on untreated fuel, as these would probably have brought out still better the effectiveness of the first stage of centrifuging. There could be no doubt that most of the harmful matter got into the fuel after it left the refinery—in the case of a marine engine mainly in the ship's bunker; Thornton Research Centre experience was that centrifuging had little effect on wear when the fuel came straight from the refinery to the engine and care was taken that it did not get contaminated *en route*. It was further felt that it should not be assumed that any contribution of abrasive matter in the fuel to cylinder wear must necessarily be of a direct nature. It had been found that unsatisfactory injection characteristics arising from wear in the high-pressure pumps and sprayer orifices could greatly influence the rate of wear and fouling in the engine.

Thornton had stated on several occasions the belief that, for fuels containing residual, the ash-forming constituents not removed by centrifuging could exert a great influence on the rate of cylinder and piston ring wear and that this wear could be out of all proportion to the sulphur content of the fuel. There was therefore agreement with the author's findings that those fuels with a high ash content demonstrated a high rate of wear in spite of centrifuging or purifying treatment, which, of course, could not be expected to influence this factor. One of the major operating problems imposed by change of fuel was that of deposits in the combustion space, in the exhaust ways and on the injector. He agreed with the author's explanation of the formation of injector tip deposits, but the author did not appear to have observed the close cyclic nature of their formation, which was their usual characteristic, and it should be pointed out that the consequences of exhaust smoking resulting from those deposits were much more serious than the author implied. The high rate of engine fouling, both in the combustion space and in the exhaust ways, that occurred at the peak of the formation of those deposits was very serious and presented a real hazard to operating efficiency.

Mr. J. D. Thorn considered Table 6 to be an unfortunate inclusion in the paper. Apart from the fact that it was based on results from certain particular fuels, there were many items of additional expenditure to be added to the cost of using the inferior fuels. For instance, the liners and rings were not the only parts which would wear; the piston ring grooves would probably wear, too. The author himself had mentioned the increased deposits which must be expected to lead to increased maintenance and also increased lubricant costs due to the more rapid deterioration of the lubricating oils. There was also the question of the amortisation of the additional equipment required for the fuel system. Even after all those things had been allowed for, there were still many imponderables. Table 6 should therefore be treated with caution.

Mr. H. Mackegg said that satisfactory engine operation could only be obtained if the correct type of centrifugal separator equipment operated at the correct capacity and temperature were used. Assuming that those conditions were applied, it would seem that there was no reason why heavy fuel should not be used for a large range of medium-sized main engines and auxiliary diesels. By "correct centrifugal separator equipment" he implied the necessity of using a centrifugal oil purifier which would give the highest constant separating efficiency throughout the treatment of a given batch of oil, followed by a centrifugal clarifier having similar characteristics. In the first (purifying) stage all water and insoluble matter down to the lowest limits was removed, and in the second (clarifying) stage the remaining finely divided matter was removed down to particle sizes of 2 to 6 microns, depending upon the characteristics of the particles. The author seemed to be rather worried about the very small amount of solids which he extracted from the clarifier. The answer was that if the purifier was doing its work properly, the amount of solids in the clarifier should only be a matter of ounces out of tons, because it was only the very finely divided stuff which came out in the clarifier, and that was the reason it was used. Experience had shown that it was not possible to produce this high degree of cleanliness in one operation, for the simple reason that the last traces of finely divided matter, which were normally removed by the clarifier, would not separate until dry oil had been obtained at the first stage. He mentioned that the temperature during treatment was a critical feature, and satisfactory results would not be obtained unless the heavy fuel oil was purified at 180 deg. Fah. So also was the temperature at injection, so that in all installations, whether marine or stationary, the method of heating the oil must receive careful consideration.

Commander (E) L. Baker said that before the war, and more particularly after the war, ships of the Blue Funnel Line had been equipped to run on boiler fuel with a maximum viscosity of 1500 seconds, this maximum viscosity for a particular ship depending solely upon the heating coils fitted in the double bottom tanks. In sixteen of the ships the auxiliary engines were also run on boiler fuel and had been for over two years. The wear figures from these engines, which had 325mm bore and ran at 375 r.p.m., were the same as when the same engines were run on marine diesel fuel, namely 2 to 3 thousandths of an inch per thousand hours. A limited amount of experience on boiler fuel had also been obtained on engines running at 600 r.p.m., but the time had been too limited to get wear figures. Deposits were somewhat heavier on boiler fuel, but they did not appear to cause difficulty in the engines or in the lubricating oils.

Professor Cave-Browne-Cave suggested that the author should run his engine at a very much higher water temperature. One of the advantages of evaporative cooling, i.e., the water circulating round the cylinder at boiling temperature and all the waste taken away as latent heat, was that the temperature of the hottest spots in the cylinder decreased. It seemed a paradox, but it was so. As soon as boiling took place on a surface which was strongly heated, there was set up a transfer of heat at right angles to the surface by the formation of steam bubbles, which was very much more effective than the heat transfer which could be obtained by pure turbulence. One of the incidental advantages of running evaporatively was that the waste heat was then useful.

Mr. J. R. P. Smith said that he would deal fully with the discussion in a written reply, and the meeting ended.

ELECTRONIC COMPUTER FOR TORONTO.—An electronic digital computer, similar to the one at Manchester University, and built by the same manufacturer, Ferranti, Ltd., has recently been completed for shipment next month to Toronto, where it will be installed in the University.

Water Intake at Coryton Refinery

THERE is under construction at Coryton, on the Thames, a refinery for the Vacuum Oil Company, Ltd. The preliminary work of preparing the site and of laying down the foundations for the power plant and the various processing units is practically complete, and some progress is being made in erecting the items of refinery plant.

For the successful operation of the refinery an enormous quantity of cooling water is required, and it has been arranged to take the necessary supplies, amounting to a daily supply of 45 million gallons, from the River Thames through a water intake jetty. This is a reinforced concrete caisson having a total weight of 4200 tons which has been built on the Mulberry principle. On Thursday of last week, at the joint invitation of the Vacuum Oil Company, Ltd., the Lummus Company, Ltd., and John Laing and Son, Ltd., the builders, we witnessed the final stage of the tow from Tilbury, where the structure had been completed afloat, and the sinking of the caisson into position opposite the refinery. Our illustration shows the caisson almost in position and ready for sinking on to the prepared bed.

The water intake unit measures 100ft in length by 53ft in breadth, and when complete will have a height of about 59ft 6in above base. The base now rests on a bed which has been dredged out to a depth of 42·5ft below the Newlyn Datum, so that the top deck will be 17ft above datum when completed. Below the bottom floor slab, which is 20ft above the base, there are three longitudinal walls and nine transverse walls, all 9in thick, which is half the thickness of the external walls. This series of compartments is linked together by valves and is formed into six main groups, so that the trim and heel of the caisson could be accurately controlled during the sinking operation. At present, in the space above the lower deck, seen in our illustration, there are several rows of columns and, in addition, bracing at two levels, and this structure will be partially incorporated into transverse walls which have yet to be built.

At mid-length, on the riverside wall of the caisson and above the lower deck, are two openings, each 10ft by 10ft, which form the water intake and are at present covered with sheet piling to prevent the ingress of water until the pump chambers are completed. There are four chambers, which house the pump suctions, and penstocks are fitted in the internal walls. When complete steel grids will cover the main openings and the water will pass through a series of finer screens before reaching the rising mains to the pumps which are to be mounted on the top deck, and which have a total capacity of 45 million gallons per day. Another piece of equipment yet to be fitted on the top deck is a chlorination unit which will reduce the bacteriological effects in the water and prevent the fouling of the piping systems.

Because of local conditions and the need for speedy delivery it was decided to build the caisson on similar lines to those adopted for the Mulberry Harbour units. A dry dock at Gravesend was obtained and adapted to provide a firm base upon which to build the structure, the height being governed by the depth of water available. The entrance to the dock, which is at Red Lion Wharf, was closed with a dam formed of sheet piling, filled with ballast, and able to withstand the water pressure at high water. In preparation for building the caisson hollow tiles, covered by a layer of building paper, were placed on a concrete screed, which was laid on the dock bottom. The floor of the caisson was laid on the building paper and the work of pouring the concrete proceeded until the walls reached a height of 12ft 6in. At this stage the sheet pile closure dam was removed and the structure was tested for water-tightness by filling with water through the eighteen 6in valves, which had been incorporated in the side walls, and then examining the walls as the tide fell.

The unit was towed to Tilbury, where work proceeded in a wet dock. From a floating boom, which entirely surrounded the structure and protected it from damage, steel fixers and joiners worked to prepare each lift of the walls for the pouring of concrete from platforms carried on scaffolding erected inside the caisson. As the height of the walls increased with each successive lift of 2ft, ballast was introduced to give the caisson a deeper draught and so keep the shuttering within reach of the men working on the boom. When the walls reached a height of 30ft the water ballast was removed and a bracketed scaffold erected around the structure, then the pouring of concrete continued until the twenty-second lift was completed. At this point some 600 tons of 15 : 1 lean concrete was laid in the bottom of the caisson, this being the amount of ballast necessary to give the draught of 29ft which was required to ensure that the unit had sufficient stability when being towed to Coryton. Before leaving Tilbury the structure was built up to a height of 52ft 6in, leaving the final two lifts and top deck to be added after it was in position at Coryton.

The timber shuttering was prefabricated, each unit being 2ft deep and varying in width from 2ft to 6ft, according to its position in the structure. Immersion equipment was used to vibrate the concrete, which had an average cube compressive strength of 6000 lb per square inch at twenty-eight days.

With the water intake jetty in position, work can go forward with the shore connections. On the down-river side a steel gantry carried on piles will be provided to carry three pipes of 42in diameter and three of 39in diameter for conveying the cooling water to the refinery. East of the pipe gantry, a reinforced concrete roadway, carried on steelwork and box piles, will give access to the shore. This roadway will be continued up-river outside the caisson and then turn shorewards at the western end of the jetty to join with a steel fender consisting of a double row of piles and cross bracing. This arrangement will provide protection for the jetty from drifting craft.

INTERNAL STRUCTURE ABOVE LOWER DECK

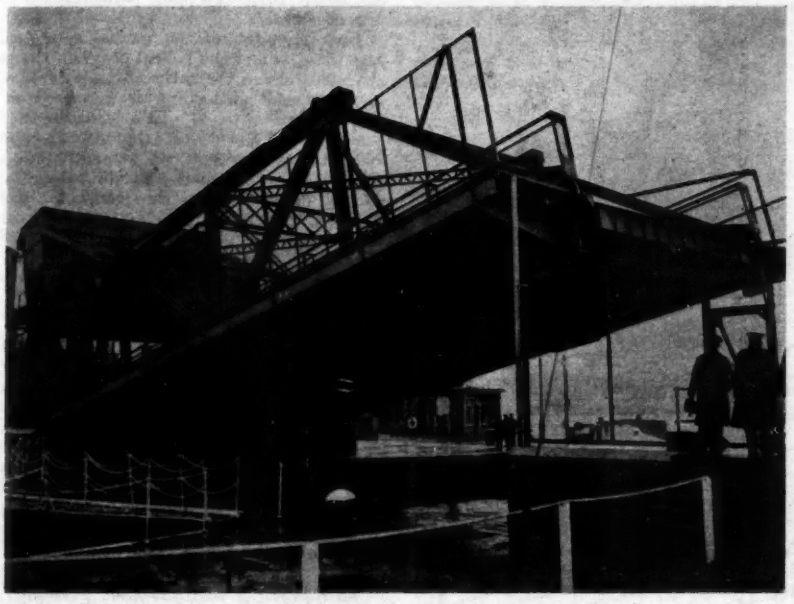
CAISSON AT CORYTON REFINERY

A Rolling Lift Bridge at Surrey Docks

ON Friday last, March 7th, the new Surrey Lock Bridge at Bermondsey was opened by Viscount Waverley, the chairman of the Port of London Authority. The bridge carries Rotherhithe Street over the Surrey Lock entrance of the Surrey Docks. It has been built to replace an old swing bridge, constructed in 1858, which had long proved an obstruction to traffic in this area, as it had only one roadway, 8ft 9in wide, flanked on each side by a footway, 4ft 6in wide. The swing bridge had also been immobilised as a result of enemy action in the last war, so that navigation through the lock entrance was restricted to the passage of barges. In addition, the continued deterioration of the old bridge had compelled the Port of London Authority to prohibit the passage of loads over 10 tons.

The new structure is a single leaf rolling lift bridge of steel construction, consisting of a front arm spanning over the lock entrance, and a rear arm forming a balanced quadrant on which the bridge rolls in raising and lowering. The clear width of the lock entrance is 54ft, and the span of the front arm is 82ft between centres of bearings. The radius of the quadrant girders is 19ft, and the length of travel is 26ft 3in. The bridge carries a roadway 25ft wide, flanked by two footways each 7ft 6in wide.

The total weight of the bridge is 720 tons, including 400 tons of counterweight in the ballast box. The bridge is balanced about the centre of the quadrant girders, except for a preponderance of 1 ton at the nose end, to prevent chattering under the passage of live load. The bridge is designed to carry the Ministry of Transport's standard loading for highway bridges.



THE SURREY LOCK BRIDGE

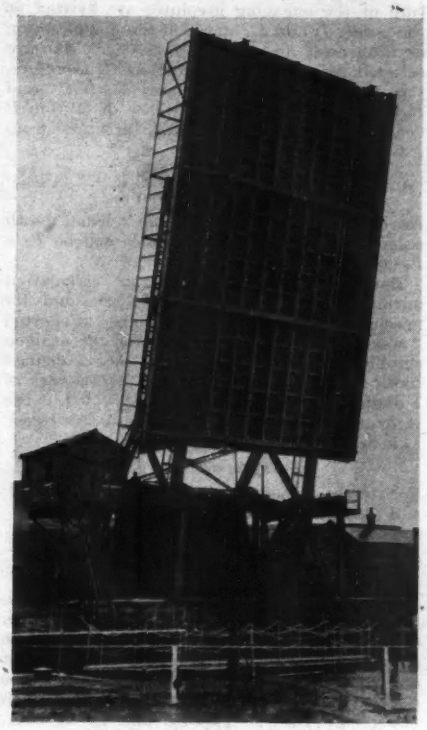
In planning the new bridge, the opportunity was taken to improve the alignment of Rotherhithe Street by eliminating two awkward bends. This realignment enabled the new bridge and approaches to be built without interfering with the traffic over the old bridge. The improved alignment and greater width of the new bridge and its better operation, have considerably relieved traffic difficulties.

The mass concrete foundation carrying the track girders bears on a stratum of ballast overlying the London clay. It was built inside a steel sheet piled cofferdam, the piles being driven to penetrate into the clay to seal the dam. The maximum pressure on the ballast is about 3 tons per square foot. The foundation is next to the old wall of the Surrey Lock, and special care was taken to avoid the load of the bridge being taken by this wall. A dry joint was left between the old and the new work, which was grouted later on, when the bridge was erected.

The bridge itself is an N-braced structure, as may be observed from the first of the illustrations reproduced herewith. The panels are each about 23ft wide, with a distance of 18ft between the centres of the top and bottom booms, and 29ft 9½in between the centres of the two main trusses. The two footpaths are cantilevered outside the main trusses on plate girder cantilevers, each some 8ft 9in long. Cross beams of plate girder construction span between the two bottom booms of the main girders; the tertiary members are rolled steel joists, and the deck consists of steel buckle plates with a concrete filling, and an asphalt waterproofing above it; longitudinal timber planking above the asphalt is bolted to the steelwork, and the road surface consists of wooden blocks, dowelled on two sides, and secured to the planking by coach screws. This form of decking has been used to keep the weight down as much as possible; the footpaths are also of timber. The structure of the span is completed by top bracing girders of lattice construction placed between the two main trusses at each panel point.

The track plates and quadrant girder plates are each 4in thick, and are of high tensile steel. A cold rolling effect, which has given trouble in some rolling lift bridges, has been allowed for by placing a diagonal joint ½in wide, at 6ft 6in centres along both of these surfaces (the joints are of opposite slope in the track plate and the quadrant girder plate above). There are teeth in the track plate which engage in slots in the quadrant girder plate as the bridge moves. These teeth are 5½in wide by 8in long, and are spaced at 2ft 2½in centres.

The bridge is operated by two electric motors on the moving leaf, each of 50 b.h.p., which act through a differential unit and drive two trains of gearing terminating in the main pinions which move along fixed racks supported on trestles outside the bridge. The motors run at 700 r.p.m., with a reduction of 162 : 1 in the gearing. Electricity supply is 3-phase a.c., at 430V for power, and single-phase at 250V for lighting, heating and control circuits, all at 50 c/s. Operation is through a master controller in the control cabin, and all the operations are interlocked so that they can only be carried out in the correct sequence. A visual indicator in the control cabin shows the stages of operation. To raise the bridge the roadway gates are first closed by hand, the nose locking bolt is withdrawn by its motor, and the leaf is then raised by the main machinery. To lower the bridge the reverse operations take place. The bridge can be raised and lowered by one main motor in fair weather conditions in three minutes, and with both motors coupled together it can be raised and lowered against a 15 lb per square foot wind pressure in three-and-a-half minutes. The brakes are designed to hold the leaf against a 30 lb per square foot wind pressure. Auxiliary hand gear is provided for use in the event of the failure of the electric supply.



THE BRIDGE RAISED

There are two pneumatic buffers, which may be observed in the first of our illustrations, at the nose of the bridge; each one consists of a damping cylinder, with the piston projecting below it to make contact with the nose bearing. Air escapes from each damping cylinder through a pipe leading to a needle valve at the centre of the bridge. The nose locking bolt, which is 3in square and of stainless steel, fits into a socket in the abutment; it is operated by a 1½ h.p. electric motor. The ballast box is provided with pockets into which blocks of concrete may be placed to trim the balance of the bridge correctly.

Surrey Lock Bridge was designed and constructed under the direction of Mr. J. Rawlinson, M.I.C.E., the chief engineer of the London County Council. The main contractor was Sir William Arrol and Co., Ltd., who supplied and erected the steelwork and machinery; the sub-contractor for the civil engineering work was Paterson and Dickinson, Ltd. The control gear was supplied by Igranic Electric Company, Ltd., and the electrical installation work was carried out by W. J. Furse and Co. (London), Ltd. The Port of London Authority and the Bermondsey Metropolitan Borough Council also collaborated in the scheme. The total cost of the work was approximately £110,000, divided between the Ministry of Transport, the Port of London Authority and the London County Council. Work was begun in April, 1949, and completed in January of this year. The new bridge will enable the Surrey Lock entrance to be used by large vessels entering or leaving the Surrey Docks.

Gear-Tooth Stresses and Rating Formulæ*

By H. E. MERRITT, M.B.E., D.Sc. (Eng.), M.I.Mech.E.†

No. II—(*Concluded from page 343, March 7th*)

Determination of Surface Stress

The general method may be described with reference to Fig. 6, in which spur gears having t and T teeth generated from a rack of 1 diametral pitch engage at a pressure angle ψ_c which may (as in "commercial" gears) correspond to the pressure angle of generation.

At any point of contact, the centres of curvature of the engaging involutes are located at the points I_1 and I_2, at which the line of action is tangential to the base circles. At any selected point of contact such as C, therefore, the radii of curvature are $R_1=I_1C$ and $R_2=I_2C$, and if l_1 is the distance of C from P (positive if measured in the direction from P to I_2), R_r is given by

$$R_r=\frac{(\frac{1}{2}t\,.\cos\psi_g\,.\tan\psi_c+l_1)(\frac{1}{2}T\,.\cos\psi_g\,.\tan\psi_c-l_1)}{\frac{1}{2}(t+T)\cos\psi_g\,.\tan\psi_c}.$$

As in regard to strength, the normal tooth reaction per inch of line contact will be $F_c=F_t\,.\sec\psi_c$, and $S_c=(F_t\,.\sec\psi_c)/R_r$.

Zone Factors.—The particular calculation outlined above is seldom necessary, and for most purposes is replaced by the use of charted "zone factors." The zone factor for a given combination of tooth numbers and a defined tooth form, for teeth generated from a rack of 1 diametral pitch and of 1in face width, is the ratio of the tangential load to the surface stress. It is denoted by Z, and

$$Z=F_t/S_c=R_r\,.\cos\psi_c.$$

For teeth of some other diametral pitch P and face width f, the relations are

$$F=(S_c\,.\,Z\,.\,f)/P$$

or

$$S_c=F\,.\,P/f\,.\,Z$$

It will be seen that, having eliminated the index 0·8, these expressions correspond in form to those for bending stress. It must be emphasised, however, that the expressions must not be used in conjunction with the earlier (British Standard) zone factors, for which $F=S_c'\,.\,Z'\,.\,f/P^{0.8}$. The S_c' and Z' as compared with S_c and Z indicate the values associated with the use of the modified criterion.

Zone Factors for Precision Gears.—The conditions are shown in Fig. 7, in which the chosen load point is CP_1. The relative radius of curvature at any point is proportional to the ordinate to a parabola projected from the base I_1I_2, whilst an ordinate to the trapezoidal load diagram represents F_c, and for all normal designs the ratio F_c/R_r will be a maximum at the point CP_1. The value of the zone factor based on this point may be derived from the values of R_1 and R_2 already given, but these involve the length of path of face contact of the pinion. A simpler sequence is to use the "tangent length" l_t corresponding to I_1C_1 in Fig. 7; then

$$l_t=0\cdot1t[5\sin^2\psi_g+100x(1+x)]^{\frac{1}{2}}$$

(where x is the ratio of the addendum to the pitch diameter of generation);

$$R_1=l_t-\pi\,.\cos\psi_g$$
$$R_1+R_2=\tfrac{1}{2}(t+T)\cos\psi_g\,.\tan\psi_c$$
$$R_2=(R_1+R_2)-R_1$$
$$Z=(R_1\,.\,R_2\,.\cos\psi_g)/(R_1+R_2).$$

Fig. 8 gives values of Z calculated in this way for teeth in which $k_p=k_w=0\cdot5$.

Zone Factors for Commercial Gears.—The

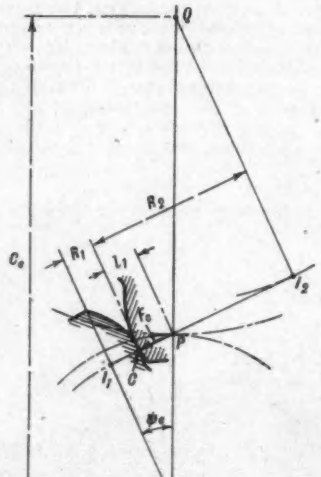


Fig. 6—*Determination of Surface Stress in Spur Gears*

conditions in this case are illustrated by Fig. 9, in which CE_1 is the chosen load point. By using the value of l_1 already given,

$$R_1=\tfrac{1}{2}t\,.\sin\psi+k_p\,.\operatorname{cosec}\psi-\tfrac{1}{2}\pi\,.\cos\psi$$
$$R_2=\tfrac{1}{2}T\,.\sin\psi-k_p\,.\operatorname{cosec}\psi+\tfrac{1}{2}\pi\,.\cos\psi$$

and

$$Z=(R_1\,.\,R_2\,.\cos\psi)/(R_1+R_2).$$

Fig. 10 gives values of Z thus determined, for teeth designed in accordance with the British Standard system already described.

Helical Gears

When considering helical gears, the situation is complicated by the distribution of load along the contact lines, which are now disposed diagonally across the faces of the teeth. The answer depends entirely upon the assumptions made about this distribution.

If a helical gear has a normal pressure angle ψ_n and a spiral angle σ, the base spiral angle σ_0 is given by

$$\sin\sigma_0=\sin\sigma\,.\cos\psi_n.$$

It can be shown that if the contact ratio on the *normal* section is r_{cn}, and a tangential load F_t lb per inch of face-width is applied, the mean intensity of load along the lines of contact (for one axial pitch or a multiple thereof) is

$$F_{mz}=(F_t\,.\sec\psi_n\,.\sec\sigma\,.\sec\sigma_0)/r_{cn}$$

whilst the mean intensity per unit of length of tooth measured along the tooth spiral is

$$F_{my}=(F_t\,.\sec\psi_n\,.\sec^2\sigma)/r_{cn}.$$

But with gears generated from a modified (B.S.) basic rack, the contact ratio on the normal section is unity. When the intensity of loading along the contact lines is assumed to be uniform and when the difference between σ and σ_0 is neglected (it is usually very small) the above expressions can be taken as equal and represented by

$$F_c=F_t\,.\sec\psi_n\,.\sec^2\sigma.$$

This corresponds to the intensity of loading which can be regarded as applied to the teeth of the virtual spur gears on the normal section. The load diagram of Fig. 9 may be taken as representing either the variation of intensity of load (the variation here being zero) at a point of contact which moves across the normal section of the virtual spur gears, or the distribution of load along the diagonal line of contact.

With helical gears of the precision class, the appropriate amount of profile modification, and the considerations influencing its choice, have also been investigated by Dr. Walker. To simplify the computation of zone factors, it is here assumed that the profile modification is similar to that which would be applied to the virtual spur gears. The result is that the load diagram of Fig. 7 now represents the distribution of load along the contact lines; and it so happens that the area and height of the load diagram are the same as those in Fig. 9 for gears of the same dimensions. Hence the intensity of loading at the chosen load-point CP_1 of the virtual spur gears is also given by the expression for commercial gears and the quantity r_{cn} disappears.

It also happens that the radii of curvature of the virtual spur gears at any point on the normal section are the same (within an approximation represented by $\cos\sigma/\cos\sigma_0$) as those of the helical teeth in a plane perpendicular to the line of contact.

But the pitch of the virtual spur gears is less than that of the helical gears on the transverse section in the ratio of $\cos\sigma$ to 1, whilst the intensity of loading is increased in the ratio of $\sec^2\sigma$ to 1. This leads to the conveniently simple result that if Y_h and Z_h respectively represent the strength and zone factors of helical gears (determined for a diametral pitch of 1 on the transverse section) and Y_{vs} and Z_{vs} represent the corresponding factors for the virtual spur gears, also for a diametral pitch of 1, then

$$Y_h=Y_{vs}\,.\cos^3\sigma$$

and

$$Z_h=Z_{vs}\,.\cos^3\sigma.$$

This result can also be extended to bevel gears.

It may be observed that in regard to strength, the effect of increasing σ is to reduce the strength factor of helical gears almost in the ratio of $\cos^3\sigma$ to 1. In regard to wear, on the other hand, Z_{vs} increases substantially with increase in σ, to an extent which broadly leaves the zone factor unaffected by the spiral angle, but for small tooth-numbers may give helical gears a small advantage in Z over spur gears.

Permissible Stresses

It is traditional in rating formulæ to arrive at a permissible working stress by multiplying a "basic stress" by a "speed factor." A permissible stress thus derived is a nominal stress, corresponding to the static application of the tangential load.

Basic Stresses.—It is not proposed to comment here, at any length, upon basic stresses. They are arrived at partly by experience and partly by interpolation, guided chiefly by ultimate tensile strength in the case of basic bending stresses, and by hardness in basic surface stresses. The point which should be emphasised is that these basic stresses (a comprehensive list is given in B.S. 545 : 1949) do not, nevertheless, correspond to a single physical property of a gear material or represent a stress which can be applied under a single specified condition, such as static loading. They are intended merely to represent the comparative loading which different materials will carry; but there is scope for much further work to determine whether the present comparisons thus provided are accurate and whether there may not, in fact, be considerable and real differences between materials having

---

* Institution of Mechanical Engineers, February 29th.

† Chief administrative engineer, Humber Ltd., Coventry.

Notation

C	Centre distance.
D	Pitch diameter of wheel.
d	Pitch diameter of pinion.
E	Modulus of elasticity.
F	Tangential load.
F_c	Normal tooth reaction per inch of length of contact line.
F_t	Tangential load at the pitch circles per inch of face width.
f	Face width.
h	Addendum reduction (topping) to give adequate bottom clearance.
I	Centre of curvature of engaging involute (spur gear).
K_{adj}	Adjusting constant.
k	Addendum coefficient.
l	Distance of any selected point of contact from the pitch point.
l_t	"Tangent-length."
M	Torque.
N	Speed of wheel, r.p.m.
n	Speed of pinion, r.p.m.
P	Diametral pitch.
p	Circular pitch.
R	Radius of curvature.
R_r	Relative radius of curvature.
r	Inverse ratio $=\frac{t}{T}$.
S	Stress.
T	Number of teeth in wheel.
t	Number of teeth in pinion.
U	Running time.
U_{eq}	Equivalent running time.
V	Pitch circle velocity, feet per minute.
V'	Sliding velocity.
X	Speed factor.
Y	Strength factor.
Z	Zone factor.
θ	Angle of inclination.
μ	Coefficient of friction.
σ	Spiral angle.
ψ	Pressure angle.

Suffixes (general)

b bending; c surface; e engagement; g generation; h helical gear; o basic; p pinion; w wheel; vs virtual spiral gears; $_1$, $_2$ distinguishing two values.

similar general physical properties but more subtle differences in composition or structure.

Speed Factors.—From the time when rating formulæ for gears were first invented, it was customary to make the speed factor a function of the pitch circle velocity ; but in the practice (with which the author was associated) later transferred to British Standard methods, the speed factor was made a function of the speed of the gear in revolutions per minute. This basis was adopted on the following grounds : first, because it makes some allowance for the total number of repetitions of stress to which a tooth may be subjected ; and, secondly, because it is convenient in facilitating the

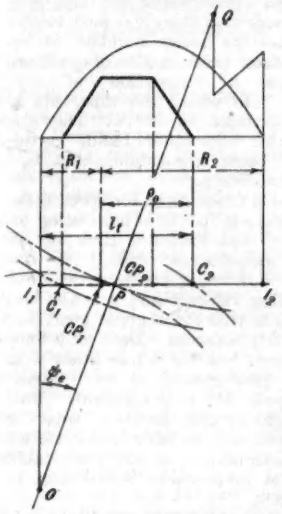


FIG. 7—*Derivation of Zone Factor for "Precision" Gears*

determination of new gear sizes, when speeds in revolutions per minute are known but pitch diameters, and hence pitch circle velocities, are not.

It was remarked earlier, in discussing criteria of surface stress, that the index 0·8 was introduced because the criterion $S_c = F_c/R_r$ appeared to rate large gears too highly ; and the speed factor was based upon the revolutions per minute. It was noted that one hypothesis concerned the effect of the oil-film. This question has been examined by Professor M'Ewen (1948), who found that the effect is proportional to R_r, unmodified by any index ; and he suggested that the probable reason for needing the index 0·8 was the use of the revolutions per minute as the basis for the speed factor ; the larger gears, with the same nominal stresses as smaller ones at the same revolutions per minute, would be running at higher pitch circle velocities. The author has pursued this line of thought, with a surprising result.

It is necessary, however, first to interpolate one or two observations about speed factors in general. Broadly, they represent the result of experience, that tooth loading ought to diminish with increase of speed ; but the way in which it should diminish is not accurately known. An obvious consideration is the increase, with speed, of dynamic increments owing to tooth errors, and the faster a gear is required to run the more accurately its teeth must be finished. Hence, a "speed-factor curve" does not represent the permissible load on a given gear over the whole of the speed range of a speed factor chart, but only the relative permissible loading on gears having an accuracy suited to their speeds.

The magnitude of the dynamic loading is very rarely known, except when it is so small as to be negligible ; Professor Tuplin (1950) has examined the problem in relation to tooth errors and elasticity, and Mr. A. Gilmour, in an unpublished monograph, has investigated the vibrations of a gear assembly taking into account the elastic constraints of the gear masses. But this and other work, whilst contributing to a general understanding of the phenomena, has not yet crystallised into a form which can be embodied in rating formulæ for everyday use.

It can be shown, however, by quite simple arguments that if two pairs of gears, to different scales, are geometrically similar in all respects, including the magnitude and distribution of tooth errors, the dynamic increments of tooth stress will be the same for both if they run at the same pitch circle velocity, which also applies if the gears are connected to similar external masses by similar elastic shafts. A prima facie argument is therefore provided for basing the speed factor upon pitch circle velocity ; and British Standard rating formulæ for wear are almost exactly equivalent to this, although it was not realised at the time when they were evolved.

That this is so, however, has now become clear. In successive changes, suggested by experience, in the form of the B.S. speed factor (X) curves in the various gear specifications there has been a steady approach towards a curve represented by $X \propto n^{-0.2}$. Hence, if S_c' and Z' represent the surface stress and zone factor (based on the criterion $S_c = F_c/R_r^{0.8}$),

$$F \propto \frac{S_c' \,.\, Z' \,.\, f}{P^{0.8}} \times \frac{1}{n^{0.2}}$$

and since $n \propto V/D \propto V \,.\, P/T$ (where n is the pinion speed, V is the pitch circle velocity, D is pitch diameter of pinion, and P is diametral pitch),

$$F \propto \frac{S_c' \,.\, Z' \,.\, f \,.\, T^{0.2}}{P} \times \frac{1}{V^{0.2}}.$$

Thus for a given tooth-combination, the allowable load is proportional to $V^{-0.2}$ and inversely proportional to P.

From a large number of numerical examples, another unforeseen feature has emerged ; in addition to the concealed speed factor $V^{-0.2}$, there is a further modification for gear ratio, which appears when the zone factor is

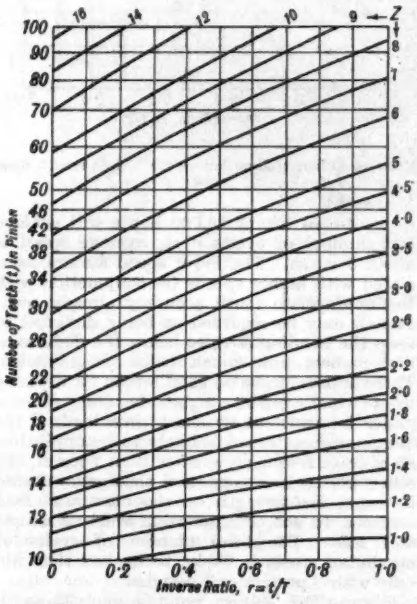


FIG. 8—*Chart of Zone Factors for "Precision" Spur Gears*

recalculated on the basis of the unmodified criterion $S_c = F_c/R_r$. When this is done, the permissible tangential load is given, very nearly, by

$$F = \frac{S_{co} \,.\, Z \,.\, f}{P}\left(\frac{1+r}{V}\right)^{0.2} \times \text{a constant}$$

for the pinion, whilst for the wheel the quantity $(1+r)$ is replaced by $(1+R)$. The speed factor for the wheel is therefore $R^{0.2}$ times that for the pinion.

In order to determine the appropriate value for the "constant," several hundred examples were calculated by both methods. Excluding cases in which $n > 5000$, the "constant" in 80 per cent of the examples, fell within ±7 per cent of the most frequent value, namely, 1·65 ; i.e., this value gives the closest agreement with B.S. ratings. But since the 40 per cent of cases between +0 and +7 per cent are presumably successful, the constant might be taken as 1·68.

Reconversion to R.p.m. Basis.—A further conclusion from the foregoing is that since the current B.S. rating formulæ for wear are in effect based upon a V-speed factor, it should be possible to reconvert the wear formulæ into a form in which only n appears, whilst leaving basic stresses unchanged and basing surface stress and zone factor upon the unmodi-

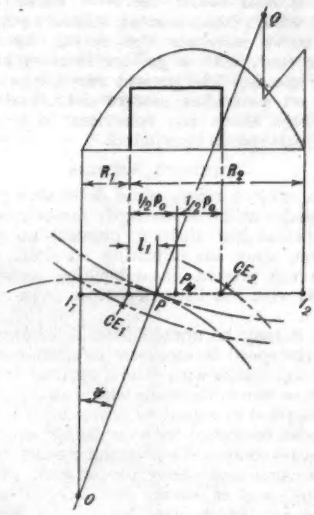


FIG. 9—*Derivation of Zone Factor for "Commercial" Gears*

fied criterion. Thus, substituting $0{\cdot}262d \,.\, n = V$, d being pitch diameter of pinion, and using the value 1·68 for the constant derived above, the expression for F for the pinion becomes :—

$$F = \frac{S_{co} \,.\, Z \,.\, f}{P^{0.8}}\left(\frac{1+r}{t \,.\, n}\right)^{0.2} \times 2{\cdot}2.$$

It should be noted that this relation and the constant 2·2 refer to "commercial" helical gears ($\psi_n = 20$ deg., $\sigma = 30$ deg.).

For purposes of new design it is convenient to have an expression for the permissible torque on the pinion, which for the above case becomes :—

$$M_p = S_{co}\left(\frac{Z}{t}\right)d^{1.8} \,.\, f\left(\frac{1+r}{n}\right)^{0.2} \times \frac{2{\cdot}2}{2}$$

whence

$$d^{1.8} \,.\, f = \frac{M_p \,.\, t}{S_{co} \,.\, Z}\left(\frac{n}{1+r}\right)^{0.2} \times \frac{2}{2{\cdot}2}.$$

After evaluating the right-hand side in any particular case, an appropriate combination of d and f can be found without difficulty.

Relative Wear Resistance of Helical and Spur Gears.—According to present B.S. ratings, the wear resistance of helical gears is from 20 to 45 per cent greater than that of spur gears having the same numbers of teeth, pitch and face-width, with an average excess of about 33 per cent. According to the recalculated zone factors, the advantage of helical over spur gears is only from 2 to 12 per cent, with an average of 4 per cent. It was not intended, when B.S. zone factors were originally calculated, that the permissible stresses in spur gears should be lower than in helical gears ; the difference lies in the original assumptions, which included an error (pointed out by Dr. Walker) in respect of relative radius of curvature.

Two courses are open : either to use the same constant of adjustment, whether it has the value 2·2, or some lower value, for both spur and helical gears, or to conclude that present B.S. ratings are satisfactory, and to adopt a lower value of the constant of adjustment for

spur gears, of, say, 1·7, which will give ratings by the recalculated factors substantially the same as the B.S. values. The second course avoids the dangers of a radical change and could be supported by the argument that spur gears in wearing tend to give rise to greater departures from uniform motion than do helical gears. Apart from the change in the constant, the expressions given above apply to both helical and spur gears.

Ratings at Extremes of Speed.—A speed factor proportional to $n^{-0.2}$ would be equal to infinity when $n=0$, and will not, therefore, cover static loading. It is suggested that for speeds less than 1 r.p.m., the value corresponding to 1 r.p.m. be used. The present (B.S.) speed factor droops below the $n^{-0.2}$ curve above about 4000 r.p.m., and at 10,000 r.p.m. the $n^{-0.2}$ curve increases the rating by about 20 per cent, with a greater increase at still higher speeds. The present curve is probably based on somewhat meagre data, and more knowledge about the behaviour of gears at really high speeds is required.

Strength Ratings

This subject raises some debatable points; the recalculation of strength factors, on the assumptions here defined, presents no special problem, since an adjusting constant would enable the present basic bending stresses to be used with but little departure from current ratings.

But it may be argued that if, in regard to wear, the speed factors were in effect based on V in conjunction with a now rational criterion of surface stress, the same considerations ought to be applied in regard to strength. The effect would be to reduce the permissible stresses in large gears compared with smaller gears running at the same revolutions per minute, which is cautious, and it would not increase overall dimensions, which are determined by wear rating and not by strength. If, therefore, the speed factor, as for wear, were made proportional to $[(1+r)/V]^{0.2}$ for the pinion, and to $[(1+R)/V]^{0.2}$ for the wheel, the rating formulæ would take the same form as for wear, viz.:

Pinion :

$$F_p=\frac{S_{bcp}\,.\,Y_p\,.\,f}{P^{0.8}}\left(\frac{1+r}{t\,.\,n}\right)^{0.2}\times K_{adj}$$

Wheel :

$$F_w=\frac{S_{bcw}\,.\,Y_w\,.\,f}{P^{0.8}}\left(\frac{1+R}{T\,.\,n}\right)^{0.2}\times K_{adj}$$

$$=F_p\,.\,\frac{S_{bcw}}{S_{bcp}}\,.\,\frac{Y_w}{Y_p}\,.\,R^{0.2}$$

where K_{adj} is the adjusting constant.

The values of K_{adj}, determined by numerical examples, are not as consistent as those for wear. This is to be expected, since the speed factor has changed its basis from revolutions per minute to feet per minute. But the chief difference is that the recalculated (commercial) strength factor for the pinion is now smaller than that of the wheel, whereas according to B.S. strength factors it is greater.

For helical (commercial) gears, a value of $K_{adj}=1\cdot9$ gives strength ratings roughly comparable with B.S. ratings for gear pairs having pinions of 4in diameter; the proportionate rating diminishes with larger and increases with smaller diameters.

It should also be noted that by B.S. 436 the same strength factors are used for both helical and spur gears, but, as recalculated, spur teeth are the stronger by approximately 40 per cent. It is suggested that, as in the case for wear, reasonable parity with B.S. ratings be preserved by giving K_{adj} a value of 1·3 for spur gears. The corresponding formulæ for torque are, of course, analogous to that given for wear rating.

It may be noted that the B.S. speed factor curve for strength droops below the $n^{-0.2}$ curve at speeds below 30 r.p.m. The author suggests that this should not occur, having regard to the slope of what is generally described as the "S/N curve" for the endurance of gear teeth (Almen, 1950), where S is the stress and N being the number of stress cycles to failure.

Intermittent and Variable Loading

A distinguished engineer remarked to the author that present rating formulæ for variable loading seem to imply that a universal quantitative solution has been found to the problem of the relation between variable load cycles and endurance. It was therefore necessary to explain that the formulæ in question were no more than guesses which had to be used in the absence of experimental evidence, in order to meet the practical need for formulæ for estimating purposes. This situation still exists.

But although guesswork is still unavoidable, it is at least desirable that the basis of the guesses should be an assumed (and stated) physical relation, so that when more precise knowledge is acquired, the errors in the assumptions can be perceived.

Strength.—Strength and wear ratings can conveniently be considered individually. It is generally accepted that the endurance limit under bending stress for materials of the kinds used for gears is reached at or below 10^7 stress cycles. An industrial gear which runs for the conventional life of 26,000 hours will achieve this number of cycles if its average speed is about 7 r.p.m. The lower speed factors associated with higher speeds (in conjunction with the appropriate tooth accuracy already mentioned) may be regarded as being designed to keep the bending stresses below the endurance limit; but, how much below is unknown. There appears to be no good reason for devising rules which permit higher bending stresses under intermittent or short time loads if the maximum tooth load is likely to be applied at an average frequency greater than 7 r.p.m. In other words, it is suggested that gears should be rated for strength on the maximum load assumed to act continuously, which is simple and safe. The total number of cycles of maximum stress is likely to be less than 10^7 only with "particular" designs.

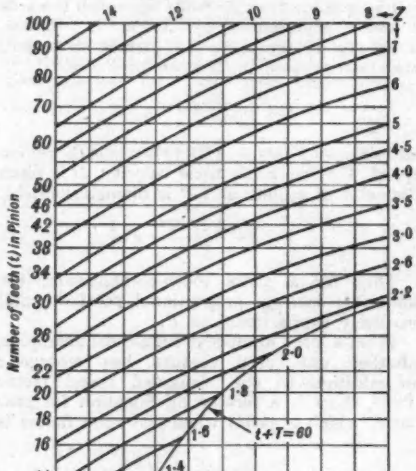


FIG. 10—*Chart of Zone Factors for "Commercial" Spur Gears*

Wear.—This subject requires more thought, partly because it is the wear and not the strength rating that determines overall gear dimensions, and partly because common sense suggests that with less frequent application of load, the surface stresses may be increased. This seems clear enough, at least in regard to the abrasive element in wear, whilst according to present evidence no endurance limit for S_c is reached at 10^7 cycles or less.

The present B.S. rules for cases of variable duration, load and speed are as follows :—

(1) The "normal rating" corresponds to a running time of twelve hours per day, under constant conditions; if the actual duration is U hours, the gears are designed for a normal rating expressed by :—

$$\text{Normal rating}=\text{actual load}\times(U/12)^{\frac{1}{x}},\ \text{where } x=3 \text{ for wear and } 7 \text{ for strength.}$$

(2) If a gear runs under variable speed and load, with a daily cycle composed of duration U_1 hours at maximum torque M_1 and speed n_1, and other components of the cycle denoted by U_2, M_2, n_2 and U_3, M_3, n_3, and so on, the "equivalent running time" to be used in the above expression—in place of the actual duration—is, for wear,

$$U_{eq}=U_1+U_2(M_2/M_1)^3(n_2/n_1)+U_3(M_3/M_1)^3(n_3/n_1)\ \ldots\ \&c.$$

in which M_1, n_1, U_1 represents the condition in which the maximum torque acts.

The foregoing expressions sometimes lead to results contrary to common sense; thus, if a gear runs at constant torque and speed for less than twelve hours per day, it is rated to carry more load than if it took twelve hours to complete the same number of revolutions. This arises because the expression for U_{eq} embodies a conception of "cumulative damage" in which the time rate of damage is proportional to $M^3\,.\,n$. The speed factor curve, on the other hand, corresponds to $M\,.\,n^{0.2}$ being a constant—that is, to $M^5\,.\,n$ being a constant.

There is much room for speculation, but few data to guide it. It is interesting to note, for example, that Professor Blok has shown that the "temperature flash" is constant if $\mu\,.\,S_{max}{}^{1.5}\,.\,V'^{0.5}$ is constant, where V' is here the sliding velocity and μ is the coefficient of friction, so that for a given gear, $\mu\,.\,S_c{}^{0.75}\,.\,n^{0.5}$ is similarly constant. Data on μ for steel gears are scarce, but for worm gears μ is approximately proportional to $V'^{-0.25}$, whence for a given gear $M^3\,.\,n$ is constant. But although this might suggest that the "wear" conditions are worst in a variable load cycle when $M^3\,.\,n$ is a maximum, it is not yet established that $M^3\,.\,n$ is numerically a criterion of rate of damage.

In the meantime the practical need for rating formulæ has already been referred to. It is suggested that when the assumption that the time rate of damage is proportional to $M^5\,.\,n$ is taken as a working hypothesis, the result has at least an element of consistency with the speed factor curve. It is then also possible to eliminate the ideas of an "equivalent running time" and "running time factor," and replace them by the "rated torque" M_r which, acting for twelve hours per day, will give the same (hypothetical) result at any chosen corresponding speed n_1 as the variable load cycle. On the assumptions, therefore, that

$$12M_r{}^5\,.\,n_r=U_1\,.\,M_1{}^5\,.\,n_1+U_2\,.\,M_2{}^5\,.\,n_2+U_3\,.\,M_3{}^5\,.\,n_3\ \ldots\ \&c.$$

the following relation holds :—

$$M_r=0\cdot61M_1[U_1+U_2(M_2/M_1)^5(n_2/n_1)+U_3(M_3/M_1)^5(n_3/n_1)\ \ldots\ ]^{0.2}$$

The "rated torque" M_r is, of course, the torque required of the gear at its normal or twelve-hour rating when running at a speed n_1; it is immaterial which component of the load cycle is designated M_1, n_1, U_1.

Stress Comparison in "Particular" Design

In this field the designer will not feel himself limited by general-purpose rating formulæ or under any compulsion to adhere to them. His only object is a fair comparison of the stresses in gears working in broadly similar circumstances.

The expressions $S_b=F\,.\,Y/f\,.\,P$ and $S_c=F\,.\,Z/f\,.\,P$ serve to compare the nominal stresses—i.e., the stresses under static application of the load F—but ignore the effect of speed, whether upon bending stress through dynamic increments or upon wear through sliding velocity. Some designers therefore use what is sometimes termed a "factored stress," in which the nominal stress is divided by the speed factor. The result corresponds, therefore, to the basic stress which would be required of the material in order that the gears might work at "normal rating" under the given load. The ratio of the actual basic stress of the material to the factored stress represents a kind of margin of safety.

A similar kind of comparison can be made when using the new factors given in this paper.

Thus comparative bending stresses may be expressed by

$$S_{bp} = \frac{F \cdot Y_p}{f \cdot P}\left(\frac{V}{1+r}\right)^{0.2}$$

$$S_{bw} = \frac{F \cdot Y_w}{f \cdot P}\left(\frac{V}{1+R}\right)^{0.2}$$

and similarly for wear, replacing Y_p and Y_w by Z. Stresses thus determined may also include a service factor or factors derived from analysis of similar transmissions, and when there is a varying load cycle, the expressions given earlier may be appropriately adapted.

American Engineering News

(By our American Correspondent)

Power From the Wind

A bill sponsored by Representative John R. Murdock, of Arizona, has been introduced in the U.S. Congress proposing the appropriation of 2,750,000 dollars for the construction of an experimental wind power generator to have a capacity of approximately 7·5MW. Following the comparatively brief but successful operation of the Smith-Putnam 1MW, single-wheel wind turbine generator situated on top of Grandpa's Knob mountain in the State of Vermont, the U.S. Federal Power Commission entered upon a wind power research project which, eventually, led to detailed mechanical, electrical and structural design studies of generating units being developed by Mr. Percy H. Thomas, of the office of the Chief Engineer of the Federal Power Commission. In these studies, two twin-wheel designs have been completely developed. The earliest was based on a maximum rated wind velocity of 34 m.p.h. and had a maximum capacity of 7·5MW. This design is adapted to about the same average wind velocity as the Grandpa's Knob installation, i.e., an average velocity of the order of 25 m.p.h. Since, however, many desirable turbine sites are expected to have average wind velocities of the order of 20 m.p.h., a second design was developed having a maximum rated wind capacity of 28 m.p.h. The capacity of the later wheel is 6·5MW, the reduction being due to the lower rated wind velocity. In embodying the lay-out in physical structures, the following basic assumptions were adopted.

(1) Wheel circle to be 200ft in diameter.

(2) 7·5MW unit to have two blades per wheel; 6·5MW unit to have three blades per wheel.

(3) Blade proper to be 80ft long with a maximum width of 14ft for the 7·5MW unit, and 9ft for the 6·5MW unit; both tapered towards the tip.

(4) Height of wheel shafts to be 475ft from the ground.

(5) Turntable to be 43ft in diameter.

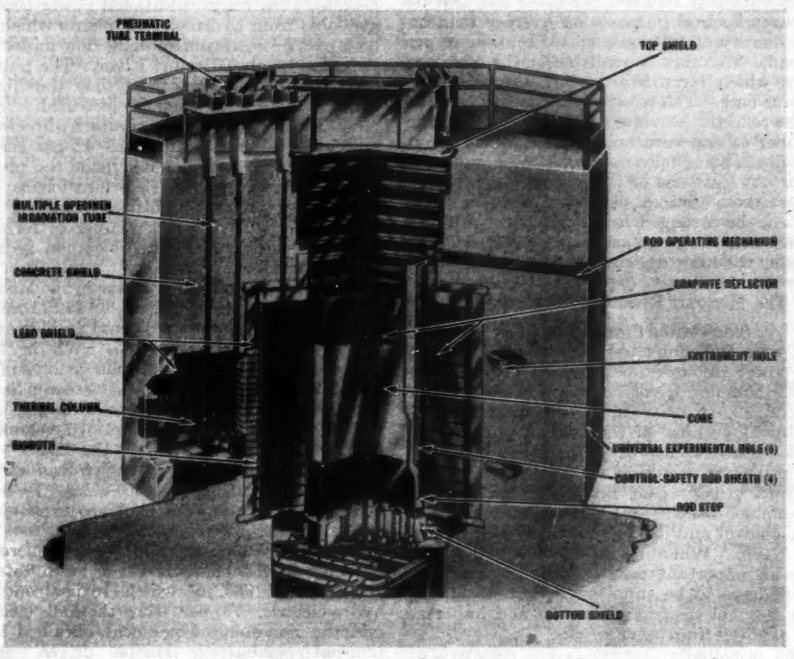
(6) Wheel speeds to be 47·50 r.p.m. for the 6·5MW unit; 42·75 r.p.m. for the 7·5MW unit.

(7) Delivery of power to be 66kV, 60 c/s a.c.

The structure of the unit as a whole consists of two turbine wheels or rotors, situated on opposite ends of a "bridge," supported on a central turntable, together with a tower carrying the turntable. The twin-wheel arrangement was selected partly to secure greater output, partly to clear the wheels from the tower structure, partly to give more free space over the turntable for the electrical and auxiliary equipment and partly to enable a very large volume of air to be tapped. For the purpose of the original study it was assumed that the wind conditions at the hypothetical site were such that it would be economical to design the particular wind turbine to operate normally on wind velocities up to 28 m.p.h. It was further assumed that it is economical to continue proportional speed operation down to a velocity 40 per cent of this value, i.e., 11·2 m.p.h. The speed of wheel rotation for 28 m.p.h. was chosen as 47·5 r.p.m. At 11·2 m.p.h. it will be, therefore, 19 r.p.m. It was further intended that on the rise of wind velocity above 28 m.p.h., the turbine should continue to operate at 47·5 r.p.m., or at speeds sufficiently lower to maintain the mechanical stresses and the load on the generator within the prescribed limits. On winds of lower velocity than 11·2 m.p.h., the wheel was intended to continue to revolve at 40 per cent of 47·5 r.p.m., or at 19 r.p.m., taking such energy as may be extracted under those conditions. As the total losses at light load and low speeds are very small, it is believed that there will be no objection to continuing the turbines in operation even on very light winds. Unless cut off, the turbine will be driven by the generator as a motor from the power "grid" when the wind fails entirely. The regulating system by which this operating control is brought about is comparatively simple. The wind turbine drives a d.c. generator and the power generated is passed through an inverted synchronous or rotary converter and a tap-changing transformer to the local "grid." The d.c. generator driven by the variable speed wind turbine tends to generate a variable voltage, which is partly controlled by its field strength. On the other hand, the d.c. leads of the rotary converter carry a voltage determined by the "grid" line voltage and the ratio of the step-up transformer. This tends to be a constant voltage as long as the ratio of the transformer is constant. The amount of energy flowing from the generator to the rotary converter will depend upon the relation of these two opposed d.c. voltages, operating in the same circuit. By changing the generator field strength and by taking advantage of the movable contacts on the step-up transformer taps, the relative voltages can be varied so that the amount of power flowing is that desired. To effect this control, an automatic regulator is provided, in which the wind velocity is balanced against the wheel speed in such an adjustment that, when the wheel speed is exactly that desired for the particular wind velocity which then exists, the regulator is balanced, wheel speed against wind velocity, and takes no action. When, on the other hand, the power exceeds the desired amount for the existing wind, the regulator moves and changes the generator field or the transformer tap connections so as to reduce the flow of energy from the generator, and vice versa, for a load too low for the prevailing wind velocity. This automatic control is extended to cover the constant load operations at wind velocities above 28 m.p.h. and constant speed operations below 11·2 m.p.h., by means of output and centrifugal governors, respectively.

A Low-Power Research Reactor

The development of a low-power atomic reactor, opening the way to a more widespread use of radio-active materials, was announced recently by North American Aviation, Incorporated, of Los Angeles. The octagonally shaped reactor, 19ft in diameter and 11ft high, still is in the testing stage. It uses enriched uranium as fuel and will produce energy at a constant rate of 160kW. It was developed under a contract from the U.S. Atomic Energy Commission by the atomic energy research department of the company. The reactor, which is said to be the smallest of its kind, is not a power generator. It operates, by intention, at too low a heat level to make this practicable. The facility is intended for such purposes as producing radio-active chemicals and streams of neutrons for medical radiation treatments. The significance of the development is that for a comparatively small sum—estimated at 1,000,000 dollars—any institution or organisation can have a facility providing for ordinary civilian purposes essentially the radiological "tools" now available only on a limited basis from such major atomic installations as the Brookhaven National Laboratory on Long Island and the Oak Ridge National Laboratory in Tennessee. In particular, this reactor has the potentiality of making available in all parts of the United States isotopes that now cannot be supplied from Brookhaven and Oak Ridge to distant sections, such as the Pacific Coast, because they decay too fast. An example is sodium 24, any quantity of which is half-exhausted, radio-actively, in 14·7 hours, thus precluding packing and transporting it very far.



LOW-POWER RESEARCH REACTOR

The design of the reactor is indicated in the accompanying illustration. The unit, which is octagonally shaped, is essentially a concrete chamber surrounding the "core," a hexagonal prism of mixed graphite and uranium, 4ft 6in in diameter and 4ft 6in high. It has been designed so that a single charge will permit operation at the rate of eight hours a day, five days a week, for at least ten years, at a nuclear energy-release rate equivalent to 160kW. Physically, the core of the reactor consists of graphite and enriched uranium sealed in an aluminium tank which is surrounded by reflector graphite. On top and bottom of the reflector and on the sides which face six of the

eight surfaces of the octagon, are several feet of concrete to shield the operating personnel from radiation. The reflector graphite is continued, beyond a bismuth shield which stops gamma rays but not neutrons, to the other two reactor faces. A removable cadmium and lead shield at these faces provides access to thermal neutrons diffusing through the graphite, thus forming a "thermal column." The shield at the top of the core is removable, too, and the core may be slipped into a thick-walled casket for transport to a reprocessing site. The reactor operator sits at a console desk in the control room overlooking the main floor, from where he watches any experiments going on. He is able to hold the reactor power within design limits by changing the setting of the cadmium-aluminium control rods, which can be moved in and out of the core. If the power should rise dangerously fast, automatic devices would trip the safety rods and shut down the reactor. It is an interesting part of the design that, even if the operator should be "asleep at the switch," or try deliberately to sabotage the reactor, it would be impossible to do so, as the reactor has a negative temperature coefficient of reactivity. In operation at 160kW the reactor will provide for experimental purposes an average neutron flux density of $10^{12}n$ per square centimetre per second. This flux is available at the exposure holes which terminate at the surface of the reactor core. The relatively large surface area of the reflector provides ample space for a large number of exposure holes. Altogether, about two dozen such holes may be fitted around the core. At least one of these may have an 18in square cross section. The experimental facilities can be arranged in different ways to suit the needs of the group using the reactor, without altering the basic design of the unit.

The Missouri River Basin

The United States Bureau of Reclamation recently completed a detailed survey of the power resources, requirements and supply of the Missouri River basin. The basin is an area of 530,000 square miles extending from the Rocky Mountains to the central part of the United States and from the Canadian border to the city of St. Louis. It is the purpose of the Missouri River basin project to aid in the development of the area through the conservation, control and use of the water resources of the basin. While hydro-electric power will play an important part in this development, it will have to be supplemented substantially with thermal electric generation and importation of power from other areas.

The principal power-producing resources of the basin are water, coal, petroleum and natural gas. The headwaters of the Missouri River and many of its tributaries rise in the high mountains of Montana, Wyoming and Colorado. The river and its tributaries drop rapidly in the western portion of the basin through deep mountain canyons and steep slopes of the foothills, then flow across the plains to its confluence with the Mississippi River. The largest amounts of existing and potential hydro-electric power lie along the eastern slope of the Rocky Mountains and the upper mainstem of the Missouri River. The areas having the greatest power requirements, on the other hand, are in the southern and eastern part of the basin. Sufficient coal reserves are known to exist within or near the basin for any foreseeable future demand. The better-quality coals are in the western section along the Rocky Mountains and in the south-eastern portion of the basin. Lignite deposits are in western North Dakota and eastern Montana. Technological advances in mining and utilisation may extend the area in which basin coals and lignites can be used for power production. Research is being carried on with respect to conversion of some solid fuels to a form more suitable for transport or for generation of power. An example of this is the underground gasification experiment of the United States Bureau of Mines at Gorgas, Alabama. Petroleum and natural gas are found in portions of the states of Montana, Wyoming, Colorado, Kansas and Nebraska. They are of limited quantities and are in demand for many purposes in the national economy. Except for residuals and waste products, petroleum and gas are not expected to be principal sources of fuel for power generation in the basin.

The phenomenal increase in the use of electric power in the Missouri River basin is considered to be characteristic of that in the United States as a whole. The average year-to-year growth in the basin during the past fifteen years is 7 per cent, a doubling in electric energy demands each ten years. This rate of growth is expected to continue between 1950 and 1960, and a 5 per cent year-to-year increase is forecast for the succeeding ten-year period. The consumption of power on farms in the basin has shown a considerable increase. While the basin as a whole ranks fairly well within the United States, with 38 per cent of its farms electrified, several of its states individually occupy a position very near the bottom. North Dakota and South Dakota, with less than one-third of all farms electrified, are among the lowest. The Bureau of Reclamation is accelerating the completion of an advance transmission grid which will be used to provide additional service to rural and urban areas in North and South Dakota, even before additional power becomes available from hydro-electric plants which will be a part of flood-control dams now under construction on the Missouri River. The State of Colorado, with 58 per cent, has the highest percentage of its farms electrified. Even Montana, with its large private hydro-electric power developments and with 42 per cent of its farms electrified, has not made the proportional progress in rural electrification as have many other parts of the United States. Potentially, it is believed, the number of farms in the basin having electric service can be more than doubled.

While requirements for power in the Missouri River basin totalled 4600MW, or 18,211 million kWh in 1950, they are expected to increase to 13,390MW, or 58,280 million kWh in 1970. These estimates are based upon reports of the Federal Power Commission, adjustments having been made for known increases in actual loads over expectations, and for potential development of new industrial activity in the basin. The greatest concentrations of power loads are in the St. Louis and Kansas City areas. By 1970, heavy concentrations of load are expected to extend farther upstream.

With regard to power supply, the generating capacity in the Missouri River basin totalled 4500MW in 1950, of which 18 per cent was hydro-electric, 78 per cent thermal electric, and the remaining 4 per cent obtained from internal combustion engine driven plant. Approximately half of the existing hydro-electric capacity is situated in the States of Montana and Wyoming. Nine federally owned and operated hydro-electric plants are situated in, or contribute directly to, the Missouri River basin power supply. They have a capacity of 158MW and an average annual generation of 872 million kWh. Ten other federal plants are under construction as features of multiple-purpose projects and twenty-two more are scheduled for construction. The total capacity of the forty-one plants will be 2600MW, and the annual generation will average 11,600 million kWh. The federal plants include developments by the Bureau of Reclamation and the U.S. Army Corps of Engineers.

The survey has shown that the supply of power available from existing plants, those under construction, and those scheduled for construction, will not be sufficient to meet the total future basin-wide load requirements. A shortage of 2000MW is expected by 1960, and 7900MW by 1970 unless additional capacity is made available. To determine the extent to which the deficiencies in capacity and energy could be met by hydro-electric power plants, a reconnaissance study was made of potential sites throughout the basin. A total of 295 sites with estimated capacities of 1MW or more were considered. Of these, 147 were judged to be good or fair and, hence, represented prospective plants worthy of further investigation. The capacity of the prospective plants, estimated to be 2100MW, is about 27 per cent of the 1970 deficiency. However, a number of the prospective sites may, upon further study, be found unsatisfactory. Existing and scheduled federal hydro-electric developments, together with existing and scheduled non-federal plants, would provide only 41 per cent of the 1970 requirements. Full development of all prospective hydro-electric sites would provide another 16 per cent. This would account for a total of 57 per cent of the estimated firm requirements for 1970. Additional thermal electric plants supplemented by available imports of electric power are, therefore, required to provide the balance. Such thermal electric plants will be required to meet future loads in most power market areas either as a supplement to hydro-electric plants or as the principal source of power. Many small plants, which are relatively inefficient, will probably be retired from operation as further integration is accomplished. An analysis has been made of forty-five possible sites for thermal electric plants throughout the basin. Plant capacities considered ranged from 40MW at several sites to 200MW for installations at Kansas City and St. Louis.

The more important additional sources of power in the basin, which further research may bring into the realm of practicability, are wind power and atomic energy. Another possible source of power is the use of direct solar energy. Wind power has a favourable prospect for early development. Experimental models of small capacity plants have been constructed and operated to further the research in this particular field. Engineering studies are now being made of larger potential installations. One of the sites being considered for such an installation is within the Missouri River basin near Laramie, Wyoming. Should such an experimental installation prove successful, this source of power could probably be developed over a considerable portion of the basin to the extent that the intermittent manner of operation of these plants could be co-ordinated with the hydro-electric and thermal electric developments.

The U.S. Bureau of Reclamation

With the advent of 1952, the U.S. Bureau of Reclamation enters its fiftieth anniversary year. During the past year a new record of achievement in hydro-electric power capacity and production on multiple-purpose projects constructed and operated by the Bureau was accomplished. The installed "name-plate" capacity of 3939·5MW in the twenty-three power plants operated by the Bureau showed an increase of 771MW over the previous year. The sales of electrical energy reached a total of approximately 21,000,000,000kWh and brought in revenues of about 35,000,000 dollars to the U.S. Treasury. The Bureau had about 6260 miles of high-voltage transmission lines in operation during 1951, while construction was continuing on nearly 3000 miles more. The operation of the 225MW power plant at Davis Dam on the Colorado River in Arizona was begun during 1951; four generating units of 108MW each were added to the productive capacity of the plant at Grand Coulee Dam on the Columbia River in Washington State; and units at power plants of the Bureau in Idaho, Colorado and Wyoming were commissioned during the year. With regard to crop production and irrigation service, the Bureau provided irrigation water for nearly a third of a million settlers on 100,000 farms, and kept in order thousands of miles of irrigation facilities throughout the arid and semi-arid Western States. These facilities included 107 storage and 68 diversion dams, more than 16,000 miles of canals and laterals, more than 3500 miles of drains, 440 pumping plants, and an estimated 6000 miles of roads. In addition to the farm population, about 1,380,000 persons living in nearby towns and villages are dependent upon the success of the sixty-two projects or divisions of projects in operation under the Federal reclamation programme. At the close of the year construction was in progress on 13 storage dams, 2 diversion dams, 10 power stations, 6 pumping plants, 360 miles of main canals, 28 miles of tunnels, 2200 miles of transmission lines, and lateral systems for 17 separate areas.

Industrial and Labour Notes

Structural Steel Exports

Speaking at the annual meeting of Redpath, Brown and Co., Ltd., which was held on Friday last, Sir Ellis Hunter, the chairman, said that, along with the whole of the steel fabricating industry, the company was concerned about the limitation imposed by Government departments on the level of export of fabricated steelwork. It was felt that such limitation might do irreparable harm to the industry's standing in overseas markets. If the Government allocation scheme precluded the issue of further export licences before late 1953, as was the case at present, it would scarcely be reasonable to expect the industry to secure much business abroad.

Restrictions on exports which had existed during the past eleven months, Sir Ellis continued, had limited the benefits which would normally accrue to this country and to those companies which had world-wide connections. The steering of export business to certain trades and countries—a short term policy occasioned by urgent economic problems—ought not, he suggested, completely to obscure the long view. If British structural engineers were unduly limited in the acceptance of overseas work it might not be easy for them to regain their position in markets abroad where there was a good deal of competition and the likelihood of even keener rivalry. Markets lost, Sir Ellis observed, were not easily regained.

Speaking of his own company, Sir Ellis said that orders in hand for home and export were substantial, but they might be affected by the steel licensing scheme, which came into operation in February. Licences were being issued very slowly and it would be some little time before the effect on current orders could be assessed. It was not known, for instance, what the effect would be upon many projects at present in the development stage. But it was to be hoped that those whose responsibility it was to advise for or against the use of steel would not be misled by exaggerated statements as to the extent of the steel shortage.

Industry and Fuel Saving

In the House of Commons last Friday a motion was submitted by Mr. Philips Price calling the attention of the Government, public administration and industry to the urgent need for comprehensive measures for the better use of coal, so that waste might be eliminated and more coal be made available for export and other purposes. Mr. Price emphasised the need for a national fuel policy, and for co-ordination between the various coal-using services.

Replying for the Government to the debate on the motion, Mr. Geoffrey Lloyd, Minister of Fuel and Power, said that there was a growing awareness on the part of industry that insulation and the installation of fuel-saving equipment usually paid a very quick return in terms of fuel saved. The Government was doing what it could to ensure that the supply of fuel-saving equipment and of the materials for insulation were adequate. It considered that, in view of the quick return normally yielded, a great many firms would insulate their factories and install fuel-saving equipment in their own interests and from their own funds. That would take up the bulk of the equipment and materials likely to be available in the immediate future. But, the Minister continued, there were some firms which, for one reason or another, might not feel able to devote capital resources of their own for the purpose, but which, none the less, could save substantial quantities of fuel if loans, say for three, four or five years, were made available to them. Accordingly, the Minister stated, the Government was informing industry, through the appropriate representative bodies, that it was prepared to make arrangements whereby experimentally, for one year in the first place, a sum of £1,000,000 would be made available at full commercial rates for loans to such firms. That sum would cover both the structural insulation of factories built before a date to be prescribed, and the installation—again by a prescribed date—of approved equipment which would save a substantial amount of fuel.

The North-East Engineering Bureau

In its annual report for 1951 the board of management of the North-East Engineering Bureau has recorded another year of progress. The report states that there was a 15 per cent increase in the membership of the Bureau, and the number of inquiries received increased by 60 per cent. Referring to the Bureau's "capacity exchange" scheme, the report says that in 1951 a complex position existed. With the announcement of the rearmament programme, certain capacity which would otherwise have been available was withheld in the hope that large orders would materialise from defence contracts. As the year proceeded, however, it became apparent that those orders were not forthcoming to the north and a greater interest was shown by members of the Bureau in routine inquiries. But, the report adds, as large rearmament contracts were being placed in the Midlands and the south, many of the main contractors in those areas solicited the assistance of the Bureau in placing subcontract work to its members. Apart from those inquiries, 634 routine inquiries were received by the Bureau, resulting in orders valued at £190,000.

In another part of the report reference is made to the Bureau's long-term policy of endeavouring to attract new industries to the area which it serves. There is also a comment about the Bureau's main objects, which are to attract new business on behalf of its members and to take an active interest in their problems. The board of management feels that the 1951 figures show that the Bureau's efforts continued to be successful throughout the year, despite the fact that shortage of materials prevented many members from obtaining contracts.

Mr. P. R. Walton continues as general manager of the Bureau, the headquarters of which are now at 109, Pilgrim Street, Newcastle upon Tyne.

Iron and Steel Output

Figures issued this week by the British Iron and Steel Federation show that the production of steel ingots and castings in February averaged 313,100 tons a week and was thus at an annual rate of 16,281,000 tons, compared with a rate of 15,234,000 tons in January and of 16,952,000 tons in February last year. Pig iron production during February averaged 197,400 tons a week, which shows an annual production rate of 10,263,000 tons, compared with 10,319,200 tons in January. In February last year, pig iron production was at an annual rate of 9,687,000 tons. The Federation says that the expansion of pig iron output is again being limited by a deficiency in coke supplies.

Britain's Overseas Trade

The Board of Trade has announced this week that, provisionally, exports of United Kingdom goods in February have been valued at £227,900,000, compared with £250,100,000 in January. If allowance is made for the smaller number of working days in February —twenty-five as against twenty-seven in January—the rate of exports was maintained at a little less than in January and was about 5 per cent more than the average for the second half of 1951. The value of re-exports in February was, at £16,200,000, again higher than for some months past. Normally February imports are below the average, but the Board of Trade says that last month's import figure of £297,200,000 probably reflects also the increasing effect of the import restrictions. The average of imports for January and February was 5 per cent lower than the average for the second half of 1951. The excess of imports (c.i.f.) over total imports (f.o.b.), which is customarily low in February, was £53,000,000, compared with £65,000,000 in February, 1951, and a monthly average of £109,000,000 from July to December last.

Diplomas in Management Studies

The Ministry of Education and the British Institute of Management have announced that they are now prepared to receive, from establishments for further education, applications for the approval of schemes for the award of diplomas in management studies. Instead of separate diplomas for each of the functional branches of management, as envisaged in the report of the Committee on Education for Management, 1947, there is to be a single diploma, which should cover two obligatory subjects, namely, management principles and management practice, and four others to be chosen from a range of optional subjects. Initially, these optional subjects should be factory management, distribution, development and design, purchasing, storekeeping and transport, personnel management, and higher business control.

Alternative schemes which may be presented by educational establishments will be considered, and further subjects may be added later to the list of optional subjects in order to meet the specialist requirements of particular professional bodies. It has been agreed by the Ministry of Education and the British Institute of Management that the diploma course should normally cover two years of part-time study and that three different subjects should be studied in each year of the course.

"The Worker in Industry"

Last year, to mark the Festival of Britain, the Ministry of Labour arranged a series of lectures under the general title of "The Worker in Industry." These lectures have now been published in the form of a booklet, which can be obtained from H.M. Stationery Office, price 3s. 6d.

The lectures appear in the order in which they were delivered, the first being by Lord Piercy, on "The Nation's Youth and Manpower Needs." A lecture by Dame Georgiana Buller is entitled "Eliminating the Wastage of Disablement," and the succeeding contributions are by Professor R. E. Lane, Lord Hankey, Mr. C. W. Guilleband, Sir Frederick Leggett, Sir George Schuster, Sir Frederick Bartlett, Professor T. U. Matthew and Sir Arthur Fleming. They deal with the effect of environment on the health and efficiency of the industrial worker; technical and scientific manpower, wages policy, the contribution of the International Labour Organisation, self-government in industry, the older worker, and accident prevention and training for industry.

Each lecture deals with different aspects of the general theme of how to ensure the greatest efficiency in the use of manpower, tracing the evolution of current thought and practice and projecting the lines of possible progress through research and experiment. A foreword to the booklet, by Sir Walter Monckton, Q.C., Minister of Labour, comments that though economic conditions may change from time to time, industry will always need human hands and brains. In its own interest, Sir Walter says, as well as in the interest of the workers who serve it, it behoves industry to use those hands and brains wisely and well.

Notes and Memoranda

Air and Water

RESEARCH SCHOLARSHIP.—The Aluminium Development Association has offered a research scholarship of £400 per annum for research in the application of light alloys to ship construction. A committee of the Institution of Naval Architects will administer the scholarship which it is hoped to award in September, 1952 Full particulars of entry, which closes on June 30th, can be obtained from the Secretary of the Institution, 10, Upper Belgrave Street, London, S.W.1.

FLYING CLASSROOMS.—Last week at the Hatfield aerodrome, the first two "Devon" aircraft of a fleet of specially-equipped trainers were formally handed over to the Royal New Zealand Air Force. The "Devon," which is the military version of the "Dove" light transport, has two "Gipsy Queen 70" engines, and de Havilland propellers. Specifications for two distinct kinds of flying classroom, one for radio training and the other for navigational training, were drawn up by the R.N.Z.A.F., in co-operation with the de Havilland Enterprise. The first two aircraft delivered were examples of each design and have accommodation for an instructor and two pupils. In the navigational trainer, each of the pupils has complete flight instrumentation, ADF, and Rebecca. Mountings and controls have been provided for a dozen other items of equipment, including a special drift recorder, and F-24 camera, an astrodome with provision for an inverted astro-compass and sextant, and an air position indicator. In the radio trainer, there is complete Marconi transmitting and receiving equipment for both pupils. Rebecca is provided also in this variant. Pilot aids include a Sperry "Gyrosyn" compass and a fan marker receiver (75Mc/s). Both variants are fitted with intercommunication equipment and provision is made in each for a Detrola range receiver and for IFF. The equipment mentioned is in addition to the normal signals and navigational radio and other normal items.

Miscellanea

THE LATE MR. H. DOWELL.—We have learned with regret of the death of Mr. Herbert Dowell, technical director of Foster, Yates and Thom, Ltd., Canal Works, Blackburn, which occurred on March 4th, following a long illness. Mr Dowell had been associated with his company for fifty-five years.

CLYDE'S MILL POWER STATION.—The British Electricity Authority has received the consent of the Ministry of Fuel and Power to the extension of the Clyde's Mill power station, Glasgow, by two 30MW turbo-alternator sets and four boilers, each of an evaporative capacity of 180,000 lb of steam an hour.

GASIFICATION OF COAL.—Mr. F. J. Dent, the newly-appointed director of the West Midlands research centre of the Gas Council, is to address a joint meeting of the Scottish section of the Institute of Fuel and the Scottish Association of Gas Managers at 6 p.m. on Friday, March 21st, at the Royal Technical College, Glasgow. He will speak on "Some Aspects of Complete Gasification of Coal."

SIXTY YEARS' SERVICE.—The directors of Ruston and Hornsby, Ltd., Lincoln, recently gave a dinner at Claridges Hotel, London, in honour of Mr. Walter Haynes, who has served on the administrative side of the company for sixty years. Mr. Haynes was secretary of the company for nearly forty years, retiring from that position in 1944. He continues to serve on the board, having been elected a director in 1937.

BOLTED FLAMEPROOF COUPLERS.—A well-illustrated 48-page brochure has been produced by British Insulated Callender's Cables, Ltd., Norfolk House, Norfolk Street, London, W.C.2, describing the company's range of bolted flameproof couplers for use in mines. With these couplers cable joints can be made and sealed with hot-pouring compound under proper workshop conditions at the surface, and the need for transporting hot compound below ground is avoided.

THE OPERATIONAL RESEARCH CLUB.—The annual open meeting of the Operational Research Club will be held on Monday next, March 17th, at 2.30 p.m., at the rooms of the Royal Society, Burlington House, Piccadilly, London, W.1. Sir Charles Goodeve, F.R.S., will preside, and the subject for discussion is "Marshalling and Queueing." The speakers will include Mr. D. V. Lindley, who will deal with "The Mathematical Theory of Marshalling and Queueing," Brigadier R. Digby-Welsh on "Applications in Hospital Administration," Dr G. C. Bell on "Applications in Aviation," and Mr. K. D. Tocher on "Unsolved Problems."

WEIR OPTIMUM DE-AERATOR.—G. and J. Weir, Ltd., Cathcart, Glasgow, has published a well-illustrated booklet called "Eliminate Corrosion in the Power Plant." It contains a useful explanation of the corrosive action of dissolved oxygen in boiler feed water, and describes the means of eliminating corrosion in land and marine power plants, with particular reference to the Weir "Optimum" de-aerator. As stated in the booklet, this equipment functions as a heater in the feed system and, although exhaust or low-pressure steam is used as an operating medium, all heat used is absorbed and retained in the feed water.

FILLET RADIUS FIXTURES.—Engineering Diamonds, Ltd., of 26, Warwick Row, Coventry, has introduced a new product, the "Endia" fillet radius fixture for the forming of radii through 90 deg. on the corners of grinding wheels. In the design developed for these units the curved slide method of rotation is used so that the three models—for ¼in, 1in and 1¼in radii—can be used on any size of grinding wheel. The angular movement of the diamond tool is limited to 90 deg., so that, providing it is correctly aligned, no wheel undercutting can take place. The fixtures have a hardened and ground setting face at an indicated distance from the centre of rotation and they have centres to facilitate mounting on cylindrical grinding machines.

ASSOCIATION OF RETIRED ENGINEERS.—We have received some particulars of an Association of Retired Engineers, which has been formed for men living in Worthing and district. Membership is open to those who are or who have been corporate members of the Institutions of Civil, Mechanical or Electrical Engineers, or of other Institutions giving equivalent status. The Association will also accept members who are of normal retiring age but are still partly employed. The Association's activities include visits to local works and other places of interest and the bringing together of members who are interested in similar hobbies. A scheme for the loan of publications between members is also being organised. The Association was formed in December last and already has a membership of forty. The honorary secretary, Mr. H. Cooch, A.M.I.E.E., 31, Shermanbury Road, Worthing, Sussex, will be happy to supply particulars of the Association.

Personal and Business

THE LANCASHIRE RIVER BOARD has changed its address to 48, West Cliff, Preston (telephone, Preston 3803).

THE NATIONAL COAL BOARD announces the appointment of Mr. Herbert Atkinson as chief officer and secretary of the Coal Industry Social Welfare Organisation.

HOPKINSONS, Ltd., Huddersfield, states that Mr. H. L. Collins has been appointed manager of the controls and soot blower division, following the retirement of Mr. W. B. Dale. Mr. S. Brook has been appointed manager of the soot blower department.

MR. FRASER W. BRUCE has been appointed managing director of Northern Aluminium Company, Ltd., Bush House, Aldwych, London, W.C.2, in succession to Mr. Kenneth Hall, who is taking up an appointment with the Aluminium, Ltd., Group of Companies in Montreal.

MR. CHARLES CONNELL, M.A., M.I.N.A., chairman of Charles Connell and Co., Ltd., Scotstoun, Glasgow, has been elected president of the Shipbuilding Conference in succession to Mr. J. Ramsay Gebbie, C.B.E., who has completed two years in office. Mr. J. W. Elliott, C.B.E., chairman of Swan, Hunter and Wigham Richardson, Ltd., Wallsend-on-Tyne, has been elected vice-president.

RICHD. W. CARR AND CO., Ltd., Pluto Works, Wadsley Bridge, Sheffield, states that the agency agreement with Brooks and Walker, Ltd., for the sale of tool steels and small tools in the London and Home Counties area, has been terminated. The area is now being worked from the company's own branch office at 38, Coram Street, London, W.C.1 (telephone, Terminus 8410). Mr. J. Leavesley Buxton is the sales director.

THE RAILWAY EXECUTIVE announces the following appointments on British Railways:—Mr. P. Protopapadakis, A.M.I.C.E., development assistant to the civil engineer, Western Region; Mr. G. D. S. Alley, assistant civil engineer (permanent way), Western Region; Mr. A. F. Wigram, A.M.I.E.E., signal and telecommunications engineer, York, North-Eastern Region; Mr. E. R. Dewdney, executive officer (marine), Railway Executive headquarters.

THE GLACIER METAL COMPANY, Ltd., has acquired the capital of Scottish Precision Castings, Ltd., Hillington Estate, Glasgow. Scottish Precision Castings, Ltd., will retain its own name and identity, although its products will be sold in all markets at home and overseas through the Glacier commercial and sales organisation.

R. H. HARRY STANGER states that on Monday, March 17th, his testing and chemical laboratories are being removed from Westminster to Summerfield House, Barnet Lane, Elstree, Herts (telephone, Elstree 1306). An office will be maintained at Broadway House, Tothill Street, Westminster, S.W.1, for the holding of consultations and for dealing with inspection work.

Contracts

THE CALEDON SHIPBUILDING AND ENGINEERING COMPANY, Ltd., is to build a tanker of 13,000 tons deadweight for the Athel Line, Ltd., and the main propelling machinery will be a Hawthorn-Doxford oil engine.

THE BURNTISLAND SHIPBUILDING COMPANY, Ltd., has contracted to build a bulk cargo ship of 11,000 tons deadweight for the Currie Line, Ltd., The ship will have a length between perpendiculars of 420ft by 59ft 3in breadth by 36ft 6in depth moulded, and a load draught of 26ft 9in. A service speed of 12 knots will be maintained by propelling machinery of 3500 b.h.p., fitted aft. The machinery will consist of two sets of diesel engines, constructed by Mirrless, Bickerton and Day, Ltd., driving a single shaft through hydraulic couplings and gearing.

DAVY AND UNITED ENGINEERING COMPANY, Ltd., Park Ironworks, Sheffield, has received a contract from Karabuk Iron and Steel Works in Turkey, for the large-scale extension and modification of an existing 28in blooming and section mill plant. The contract will involve the supply of more than 1000 tons of new mill machinery and hydraulic equipment. The Karabuk Iron and Steel Works, situated in Northern Turkey, constitute the only integrated steel plant in Turkey and therefore stand in important relationship to the economy of that country. The extensive reconstruction of the plant which is now being undertaken, has as its primary object the raising of output to approximately twice its present annual level.

LAST month, the British Electricity Authority placed contracts for equipment for power stations, transforming stations and transmission lines amounting in the aggregate to £10,764,167. The principal contracts include: Brunswick Wharf power station, one 60MW turbo-generator, feed heating and condensing plant (Metropolitan-Vickers Electrical Company, Ltd.), and 3·3kV switchgear (English Electric Company, Ltd.); Marchwood power station, near Southampton, two 60MW turbo-generators (British Thomson-Houston Company, Ltd.), and generator transformers (Ferranti, Ltd.); East Yelland power station, near Barnstaple, condensing plant (G. and J. Weir, Ltd.); Drakelow power station, Burton-on-Trent, ash-handling plant (International Combustion, Ltd.); Northampton power station, one 30MW turbo-generator, feed heating and condensing plant (Brush Electrical Engineering Company); Nottingham power station, one 60MW turbo-generator (Metropolitan-Vickers Electrical Company, Ltd.); Hams Hall "C" power station, near Birmingham, condensing and feed heating plant for three 60MW turbo-generator sets (Worthington-Simpson, Ltd.), and transformers (General Electric Company, Ltd.); Walsall power station, twelve 150,000 lb per hour boilers (Babcock and Wilcox, Ltd.); Ince power station, near Ellesmere Port, two 60MW turbo-generators (General Electric Company, Ltd.); Skelton Grange power station, Leeds, one 60MW turbo-generator, feed heating and condensing plant (C. A. Parsons and Co., Ltd.), and steel frame for boiler-house, precipitator bay and turbine house operating floor (Dorman Long and Co.); Thornhill power station, near Dewsbury, one 200,000 lb per hour boiler (Mitchell Engineering, Ltd.); Stella South power station, near Newcastle upon Tyne, coal handling plant (Robert Dempster and Sons, Ltd.); Huncoat power station, Accrington, condensing and feed heating plant for two 30MW turbo-generators (Hick Hargreaves and Co., Ltd.); Sundon substation, Bedfordshire, 132kV, 2500MVA switchgear (English Electric Company, Ltd.); Rayleigh-Chelmsford-Braintree, 132kV overhead line (Watsham's, Ltd.); Felinfoed-Ammanford-Ystradgynlais, South Wales, 132kV overhead lines (British Insulated Callender's Construction Company, Ltd.), and Creyke Beck substation, Yorks, 132kV, 2500MVA switchgear (A. Reyrolle and Co., Ltd.).

British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. each.

ELECTRICAL ENGINEERING

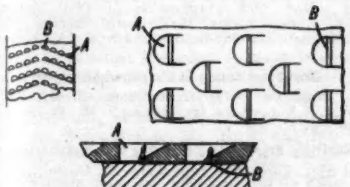
665,601. May 17, 1946.—ELECTRICALLY INSULATING MATERIALS, N.V. Philips Gloeilampenfabrieken, of Emmasingel, Eindhoven, The Netherlands.

The invention relates to electrically insulating materials formed by treating a filling material, comprising a vegetable fibrous or cellular substance, with a plastic. In one form it comprises the use of cotton fabric or paper impregnated with a thermoplastic nitrocellulose or asphalt, the fabric or paper being pre-heated before impregnation. It may, for example, be heated for half an hour to about 250 deg. Cent. Its absorption of moisture is thus reduced to an extent which renders the product very suitable for use in electric equipment. In another form the invention uses cork powder as the filling substance, and a phenol-formaldehyde or cresol-formaldehyde artificial resin as the plastic, the cork powder being pre-heated for a few hours at about 150 deg. Cent. A plate moulded from this material, after having remained in boiling water for one day, was very resistant to moisture and, further, had a bending strength which was one and a half times as great as that of a plate made from cork which had not been pre-heated. Its electrical properties, especially dielectric losses and breakdown voltage, are appreciably superior to those of a product containing untreated cork. Alternatively, the invention comprises wood flour as the filling substance, which is preheated. The plastic used for impregnating it is a phenol-formaldehyde or urea-formaldehyde resin.—*January* 30, 1952.

WORKSHOP TOOLS AND APPLIANCES

666,622. November 8, 1948.—CUTTING AND ABRADING TOOLS, Christopher Hodgson Booth and Harry Bool Hardwick, both of Bessemer Building, Carlisle Street, Sheffield.

The cutting strip illustrated in the top left-hand drawing consists of a strip of steel formed with a number of "D"-shaped holes *A*, which are arranged in "V"-shaped or chevron-shaped rows. The straight edge of each hole is sharpened, hardened and upset as described in Specification No. 666,621, to form a cutting edge, so that with the staggered arrangement of holes the edges in adjacent rows combine to provide, in effect, continuous cutting edges. The top right-hand drawing shows in greater detail the form of the cutting edges. Each

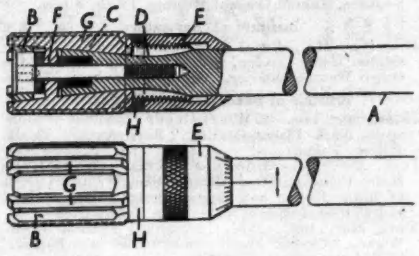


No. 666,622

edge *B* has a clearance angle relative to the surface of the strip and an angle of rake. The extent by which the edge *B* is upset increases from nil at the ends of the edge to about 0·015 of an inch at the centre. The extent of the upset is varied for different uses to which the tool is to be put. The lower drawing shows the cutting edges in operation on a workpiece and it will be noticed that the chips are directed through the holes *A*. In the specification the invention is shown as applied to files, rasps and band and disc abrading machines. —*February* 13, 1952.

666,322. April 12, 1948.—EXPANDING REAMERS, Victory Engineers, Ltd., of 143, Church Street, Stoke Newington, London, N.16, and Robert Fishwick, of 21, Devonshire Close, London, W.1.

With the form of reamer illustrated, a reamer body of solid steel *A* has at one end an enlarged portion *B* having six peripheral longitudinal slots *C*, the base of each slot being flat and inclined to the axis of the body to about 5½ deg. The slots extend somewhat beyond the enlarged part of an adjacent part *D*, which is threaded to engage an adjustment sleeve *E*, which acts as a stop to limit longitudinal movement of the blades. The enlarged end of the body is threaded at its inner end and a screw in this hole affects the movement of the blades in one direction, directly or indirectly through a series of lugs *F* projecting radially inwards from cutter blades *G*. A washer with a slightly conical face is interposed between the lugs and the screw head. In order to expand the reamer, the central screw is eased back and the graduated sleeve rotated to its new position before the screw is retightened. During the operation of



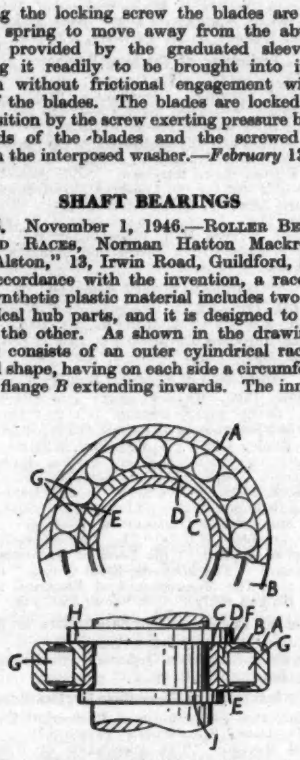
No. 666,322

releasing the locking screw the blades are forced by the spring to move away from the abutment surface provided by the graduated sleeve thus enabling it readily to be brought into its new position without frictional engagement with the ends of the blades. The blades are locked in the new position by the screw exerting pressure between the ends of the blades and the screwed sleeve through the interposed washer.—*February* 13, 1952.

SHAFT BEARINGS

666,395. November 1, 1946.—ROLLER BEARINGS AND RACES, Norman Hatton Mackrow, of "Alston," 13, Irwin Road, Guildford, Surrey.

In accordance with the invention, a race made from synthetic plastic material includes two hollow cylindrical hub parts, and it is designed to fit one within the other. As shown in the drawing, the bearing consists of an outer cylindrical race *A* of channel shape, having on each side a circumferential wall or flange *B* extending inwards. The inner race



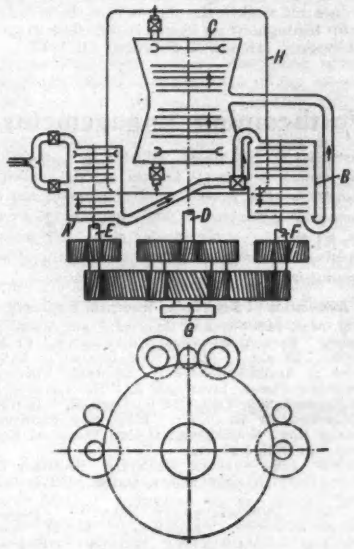
No. 666,395

of the bearing consists of two cylindrical hub parts *C* and *D*, press fitted one within the other. The hub part *C* has one circumferential flange *E* extending outwards at right angles. The outer hub part *D* has one circumferential flange *F* extending outwards at right angles. To assemble the bearing, rollers *G* are fitted into the outer race *A*, the outer hub *D* is placed in position and then the inner hub *C* is forced into it. The flanges of the inner and outer hubs form the sides of the inner race. The two race parts *C* and *D* are retained between a shoulder *H* on the shaft, and a nut or collar *J*. The invention can be applied both to the inner and outer races of a roller bearing.—*February* 13, 1952.

MARINE STEAM TURBINES

666,333. February 8, 1949.—GEARED COMPOUND STEAM TURBINE PLANT, Metropolitan-Vickers Electrical Company, Ltd., of St. Paul's Corner, 1–3, St. Paul's Churchyard, London, E.C.4. (*Inventors: Joseph Stanley Hall and Joseph Clare London.*)

According to the invention, a geared compound steam turbine plant comprises high-, intermediate- and low-pressure steam turbines which are arranged in series steam flow relation, but designed to operate on separate driving shafts interconnected through reduction gearing for driving a common output shaft. The high- and intermediate-pressure turbines are each provided with a main blading stage or set of stages for operation at maximum power at a high speed and with an additional stage or set of stages for operation at cruising or low-power at a low speed. The operating steam is supplied to the main stage or stages of each turbine for maximum power operation and to both the additional stage or stages and the main stage or stages for cruising or low-power operation. As shown in the upper drawing, the plant includes high-, intermediate- and low-pressure steam turbines *A*, *B* and *C* respectively, arranged with their longitudinal axes parallel to each other and each having separate driving shafts *D*, *E* and *F* respectively, which are coupled to the propeller shaft *G* through double reduction gear trains. The high and intermediate pressure turbines are disposed in the horizontal plane of the propeller



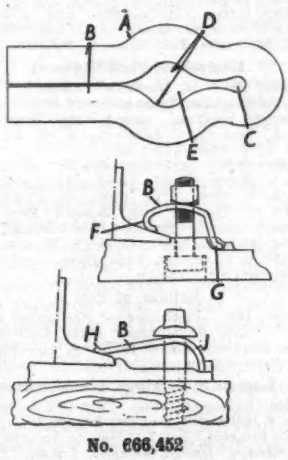
No. 666,333

shaft axis and on each side of this shaft diametrically opposite one another. The low-pressure turbine is arranged above the level of the high and intermediate-pressure turbines and is carried on the upper surface of a condenser structure *H*. The steam flow is shown by the arrows and the lower view shows the gearing. In the specification a detailed description of the control valves is given. —*February* 13, 1952.

RAILWAY ENGINEERING

666,452. October 18, 1949.—SPRING CLIP FOR SECURING FLAT-BOTTOM RAILS, Henry Williams, Ltd., and Owen Richard Williams, both of Railway Appliances Works, Darlington.

As shown in the upper drawing, the clip is formed of a strip of metal *A* of rectangular cross section, bent on itself edge to edge to form two closely adjacent limbs *B*, the broad faces lying in the same plane. A substantially circular gap *C* is formed at the closed end to ensure that the metal at that end will not be excessively stressed when bent. During or subsequent to such a bending operation each limb is bent as at *D* so that together they form a bolt hole *E*. In the construction of the clip shown in the centre



No. 666,452

drawing the free ends of the limbs are turned downwards and inwards as at *F* to bear on the bottom flange of a rail, while the closed end is turned downwards to form a straight strut, the lower end of which is turned outwards as at *G*, to rest in a recess on a crossing plate. In the construction of clip shown in the lower drawing the free ends of the limbs *B* are turned slightly upwards as at *H*, while the closed end is bent down as at *J* to form a strut,

the clip so fashioned being then heat-treated to impart the necessary resiliency. This clip is used on a bearing plate which rests on a wooden sleeper, a coach screw being inserted through the hole and a hole in the bearing plate on which rests the rail, and into the wooden sleeper. The head of the screw bears on the clip to cause it to bear with the required pressure on the bottom flange of the rail. It will be noted that the metal bearing plate is provided with a projection which engages the end of the strut *J* and by which the clip is kept in position. By the improved construction the bolt hole does not weaken the clip, so that the breadth of the clip throughout its length is sufficient to give it the necessary strength.—*February* 13, 1952.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

Association of Supervising Electrical Engineers

To-day, Mar. 14*th.*—CREWE BRANCH: Crewe Arms Hotel, Crewe, "Factory Electrical Maintenance," C. Maddocks, 7.30 p.m.——LIVERPOOL BRANCH: Laboratories of Applied Electricity, Liverpool University, Brownlow Street, Liverpool, 3, "The Cathode Ray Oscillograph as a Tool," R. C. Turnock, 7.30 p.m.——NOTTINGHAM BRANCH: Electricity Showrooms, Smithy Row, Nottingham, "Auto Electrical Equipment," F. Bull, 7.30 p.m.

Sat., Mar. 15*th.*—OXFORD BRANCH: Southern Electricity Board, George Street, Oxford, "Television," 3 p.m.

Wed., Mar. 19*th.*—COVENTRY BRANCH: Technical College, Coventry, "Estimating," W. H. Brooks, 7.15 p.m.——MANCHESTER BRANCH: Engineers' Club, Albert Square, Manchester, Film Show, 7.30 p.m.

British Institution of Radio Engineers

To-day Mar. 14*th.*—SCOTTISH SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "The Future of Broadcasting," Paul Adorian, 7 p.m.

Wed., Mar. 19*th.*—S. MIDLAND SECTION: Public Library, Rugby, "The Application of Magnetic Amplifiers to Industrial Measurement and Control," H. M. Gale, 7.15 p.m.

Cleveland Institution of Engineers

Fri., Mar. 21*st.*—Cleveland Scientific and Technical Institution, Corporation Road, Middlesbrough, "The Measuring of Reheating Furnace Performance," F. A. Gray, 6.30 p.m.

Ex-British-Westinghouse Association

Fri., Mar. 21*st.*—Connaught Rooms, London, W.C.2, Annual Re-Union, 6 p.m.

Illuminating Engineering Society

To-day, Mar. 14*th.*—BIRMINGHAM CENTRE: Imperial Hotel, Temple Street, Birmingham, Annual General Meeting, "The Physical Principles Governing Fittings Design," W. H. Willott, 6 p.m.

Mon., Mar. 17*th.*—SHEFFIELD CENTRE: The University, Western Bank, Sheffield, "Colour," W. J. Wellwood Ferguson, 6.30 p.m.

Thurs., Mar, 20*th.*—BRADFORD GROUP: Yorkshire Electricity Board, 45–53, Sunbridge Road, Bradford, "Black Light, its Effect and Application," H. L. Privett, 7.30 p.m.

Fri., Mar. 21*st.*—GLOUCESTER AND CHELTENHAM CENTRE: General Electric Co., Ltd., St. Aldgate Street, Gloucester, Film Show, 6.15 p.m.

Incorporated Plant Engineers

Wed., Mar. 19*th.*—E. MIDLANDS BRANCH: Welbeck Hotel, Nottingham, Annual General Meeting, 7 p.m.——WESTERN BRANCH: Grand Hotel, Bristol, Annual General Meeting, "Applications of Hydraulics," Frank H. Towler, 7.15 p.m.

Thurs., Mar. 20*th.*—LIVERPOOL AND N. WALES BRANCH: Radiant House, Bold Street, Liverpool, Annual General Meeting, 7.15 p.m.——PETERBOROUGH BRANCH: Eastern Gas Board's Demonstration Theatre, Church Street, Peterborough, Annual General Meeting, 7.30 p.m.——S. WALES BRANCH: Institute of Engineers, Park Place, Cardiff, Annual General Meeting, 7.15 p.m.

Institute of Fuel

Tues., Mar. 18*th.*—Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, "Fuel, Heat and Power Auditing," L. Clegg and J. Price Walters, 5.30 p.m.

Institute of Industrial Administration

Wed., Mar. 19*th.*—LONDON CENTRE: Management House, 8, Hill Street, Berkeley Square, W.1, "Management in Practice," No. 7, "How to Achieve Increased Productivity," Ian A. Marriott, 7 p.m.

Institute of Industrial Supervisors

Wed., Mar. 19*th.*—N.W. SECTION: Unity Hall, Greek Street, Stockport, "Organisation for Production," W. A. Melhuish, 8 p.m.

Thurs., Mar. 20*th.*—BRISTOL SECTION: Grand Hotel, Bristol, "Motion Study on the Shop Floor," N. G. Reece, 7.30 p.m.——NEWARK SECTION: County Technical College, Newark, "What the Cost Accountant Requires from Shop Supervision," T. W. Badgery, 7.30 p.m.

Institute of Marine Engineers

Fri., Mar. 21*st.*—College of Technology, Liverpool, "Gas Turbines," A. W. Pope, 7 p.m.

Institute of Metals

Mon., Mar. 17*th.*—SHEFFIELD LOCAL SECTION: The University, St. George's Square, Sheffield, Annual General Meeting, "Bearings and Bearing Alloys," R. T. Rolfe, 7.30 p.m.

Tues., Mar. 18*th.*—S. WALES LOCAL SECTION: University College, Metallurgy Department, Singleton Park, Swansea, Annual General Meeting, Films, 6 p.m.

Institute of Navigation

Fri., Mar. 21*st.*—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Navigation and the Ocean Weather Service," C. E. N. Frankcom, 5 p.m.

Institute of Road Transport Engineers

To-day, Mar. 14*th.*—S. WALES GROUP: Institute of Engineers, Park Place, Cardiff, "Rear Axles," R. H. Wilson, 7 p.m.

Tues., Mar. 18*th.*—MIDLANDS CENTRE: White Horse Hotel, Congreve Street, Birmingham, "Some Aspects of Motor Racing and Engine Design," Reg. Parnell and Bob Gerard, 7.30 p.m.

Wed., Mar. 19*th.*—N.W. CENTRE: Victoria Hotel, Wigan, "Chassis Frame Construction and Repair," C. F. Cunningham, 7.30 p.m.

Thurs., Mar. 20*th.*—N.E. CENTRE: Hotel Metropole, Leeds, "All Metal Bodies," H. A. Cooke, 7.30 p.m.——LONDON BRANCH: Royal Society of Arts, John Adam Street, London, W.C.2, "Pistons, Rings and Cylinder Liners," G. W. Yarwood, 6.30 p.m.

Institution of Chemical Engineers

To-day, Mar. 14*th.*—N.E. CENTRE GRADUATES' AND STUDENTS' SECTION: Stephenson Building, Claremont Road, Newcastle upon Tyne, Annual Meeting, followed by Technical Films, 6.15 p.m.

Thurs., Mar. 20*th.*—YORKSHIRE CENTRE GRADUATES' AND STUDENTS' SECTION: College of Technology, Great Horton Road, Bradford, "Some Aspects of the Design of Plant for the Conservation of Sulphur and Sulphuric Acid," J. M. Solbett, 7 p.m.

Fri., Mar. 21*st.*—LONDON GRADUATES' AND STUDENTS' SECTION: Caxton Hall, Westminster, S.W.1, "The Design of Bubble Cap Distillation Columns," D. C. Freshwater, 6.30 p.m.

Institution of Civil Engineers

Tues., Mar. 18*th.*—Great George Street, Westminster, London, S.W.1, "The Most Recent Dams by the 'Societa Adriatica Di Elettricita (S.A.D.E.)' in the Eastern Alps," Carlo Semenza, 5.30 p.m.

Institution of Electrical Engineers

Tues., Mar. 18*th.*—MEASUREMENTS AND SUPPLY SECTION: Savoy Place, London, W.C.2, "The Application of Transductors as Relays to Protective Gear," R. K. Edgley and F. L. Hamilton, 5.30 p.m.——N. MIDLAND CENTRE: Lighting Service Bureau, 24, Aire Street, Leeds, "The Characteristics and Control of Rectifier-Motor Variable-Speed Drives," P. Bingley, 6.30 p.m.

Thurs., Mar. 20*th.*—UTILISATION SECTION: Savoy Place, London, W.C.2, "The Individual-Generator System as Applied to the Tandem Cold-Strip Mill," D. Bolton; "The Magnetic-Fluid Clutch," E. J. R. Hardy; "The Measurement of Electrical Activity in the Human Body," J. C. Shaw, 5.30 p.m.

Institution of Engineers and Shipbuilders in Scotland

To-day, Mar. 14*th.*—University College, Dundee, "Higher Tensile Short-Link Steel Chain and Chain Slings," W. Gibson Biggart, 7.15 p.m.

Institution of Locomotive Engineers

Wed., Mar. 19*th.*—Institution of Mechanical Engineers, Storey's Gate, St. James's Park, S.W.1, Annual General Meeting, "The Application of Welding to Locomotive Boiler Copper Fireboxes," J. F. Harrison, 5.30 p.m.

Institution of Mechanical Engineers

To-day, Mar. 14*th.*—Storey's Gate, St. James's Park, London, S.W.1, "Basic Engineering Standards and Their Place in Design," G. C. Adams, 5.30 p.m.——N.E. BRANCH GRADUATES' SECTION: Head, Wrightson and Co., Ltd., Teesdale Ironworks, Thornaby-on-Tees, "Water Power," C. W. D. Carradice, 7 p.m.

Mon., Mar. 17*th.*—MIDLAND BRANCH, GRADUATES' SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Atomic Energy," 6.30 p.m.——DERBY A.D. CENTRE: Midland Hotel, Derby, Annual General Meeting, Chairman's Address, A. A. Rubbra, 7 p.m.——SCOTTISH A.D. CENTRE: Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, "The Incidence of Cavitation in Journal Bearings," H. L. McBroom, 7.30 p.m.

Tues., Mar. 18*th.*—LUTON A.D. CENTRE: Town Hall, Luton, "The Design and Development of Very Large Road Haulage Vehicles," C. E. Burton, 7.30 p.m.

Wed., Mar. 19*th.*—WESTERN BRANCH: College of Technology, Unity Street, Bristol, "The Manufacture of Friction Linings and its Engineering Problems," J. G. Remington, 7 p.m.——N.W. A.D. CENTRE: The University, Leeds, "Development Problems Experienced in Engines of Unorthodox Design," C. B. Grandfield, 7.30 p.m.

Thurs., Mar. 20*th.*—MIDLAND BRANCH: James Watt Memorial Institute, Great Charles Street, Birmingham, "Gas-Turbine Development," B. E. G. Forsling, 6 p.m.

Fri., Mar. 21*st.*—Storey's Gate, St. James's Park, London, S.W.1, "Centrifugal Pumps in Steam Power Stations," R. Pennington, 5.30 p.m.——E. MIDLAND BRANCH: Technical College, Lincoln, "Combined Power and Process Work," A. Stewart, 7.15 p.m.——SOUTHERN BRANCH, GRADUATES' SECTION: Municipal College, Bournemouth, "Design Problems of a Refrigerated Decompression Chamber," T. V. Small, 6.30 p.m.

Institution of Production Engineers

To-day, Mar. 14*th.*—EASTERN COUNTIES SECTION: Public Library, Ipswich, Annual General Meeting, 6.30 p.m., "Practical Gear Production," L. Westley Smith, 7.30 p.m.——STOKE-ON-TRENT SECTION: Technical College, Cauldon Place, Stoke-on-Trent, Annual General Meeting, "Selection and Training of Foremen," W. H. R. Dalley, 7 p.m.

Mon., Mar. 17*th.*—DERBY SECTION: Midland Hotel, Derby, Annual General Meeting, 7 p.m.——MANCHESTER SECTION: College of Technology, Sackville Street, Manchester, Annual General Meeting, 6.30 p.m., "Noise and Vibration in Machinery," A. J. King, 7.30 p.m.——N.E. SECTION: N. of England Institute of Mining and Mechanical Engineers, Neville Hall, Newcastle upon Tyne, Address by K. C. Appleyard, 7 p.m.

Tues., Mar. 18*th.*—MANCHESTER GRADUATE SECTION: Reynolds Hall, College of Technology, Manchester, 1, Annual General Meeting, 6.45 p.m., Film Show, 7.15 p.m.

Wed., Mar. 19*th.*—Royal Empire Society, 18, Northumberland Avenue, London, W.C.2, Sir Alfred Herbert Paper, "The Development of Engineering Metrology," F. H. Rolt, 7 p.m.——BIRMINGHAM SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, Annual General Meeting, "A Broader Conception of Productivity and its Measurement," F. G. S. English, 7 p.m.——COVENTRY GRADUATE SECTION: Geisha Cafe, Hertford Street, Coventry, "Developments in Tooling Technique on Automatics," H. R. Adcock, 7.15 p.m.

Thurs., Mar. 20*th.*—GLASGOW SECTION: Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, "Electronic Control of Machine Tools and Self Regulating Systems," S. A. Ghalib, 7.30 p.m.——LEICESTER SECTION: College of Art and Technology, The Newarke, Leicester, Annual General Meeting, Film, "Lubrication," 7 p.m.——LONDON SECTION: Old Ship Hotel, Brighton, "Costing as an Aid to Management," H. H. Norcross, 7 p.m.——S. ESSEX SECTION: Mid-Essex Technical College, Chelmsford, "Industrial Finishes and Film Spray Technique," E. W. Blaber, 7.30 p.m.——WOLVERHAMPTON GRADUATE SECTION: Civic Hall, Corporation Street, Wolverhampton, Annual General Meeting, "Efficient Tooling for Production," B. Holloway, 7 p.m.

Institution of Structural Engineers

Wed., Mar. 19*th.*—LANCASHIRE AND CHESHIRE BRANCH: Reynolds Hall, College of Technology, Manchester, "Some Aspects of Soil Mechanics with Reference to Foundations," G. G. Meyerhof, 6.30 p.m.——YORKSHIRE BRANCH: Great Northern Hotel, Leeds, "Problems in Foundation Engineering," Hugh B. Sutherland, 6.30 p.m.

Junior Institution of Engineers

Fri., Mar. 21*st.*—39, Victoria Street, London, S.W.1, "Industrialists in the New Towns," A. S. Ladley, 6.30 p.m.

Manchester Association of Engineers

Fri., Mar. 21*st.*—Engineers' Club, Albert Square, Manchester, Annual General Meeting, "Training for Management," F. C. Lawrence, 6.45 p.m.

North-East Coast Institution of Engineers and Shipbuilders

Fri., Mar. 21*st.*—Mining Institute, Newcastle upon Tyne, "Modern Foundry Practice," T. W. Bushell 6.45 p.m.

Royal Aeronautical Society

Thurs., Mar. 20*th.*—Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, "Terminal Air Traffic Control," E. A. Whiteley, 6 p.m.

Royal Institution of Chartered Surveyors

Tues., Mar. 18*th.*—12, Great George Street, London, S.W.1, "Valuations for Rating," H. D. S. Stiles, 6.30 p.m.

Sheffield Society of Engineers and Metallurgists

Mon., Mar. 17*th.*—The University, St. George's Square, Sheffield, "Bearings and Bearing Alloys," R. T. Rolfe, 7.30 p.m.

Society of Chemical Industry

Thurs., Mar. 20*th.*—ROAD AND BUILDING MATERIALS GROUP: Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "The Constitution and Properties of Sand-Lime Bricks," G. E. Bessey, 6 p.m.

Launches and Trial Trips

KURUTAI, cargo liner; built by Alexander Stephen and Sons, Ltd., for the Union Steam Ship Company of New Zealand, Ltd.; length 325ft, breadth 50ft, depth 26ft, deadweight 5300 tons; Stephen-Sulzer single-acting diesel engine, six cylinders 600mm diameter by 1040mm stroke, 2410 b.h.p. at 128 r.p.m., overload 3000 b.h.p. at 150 r.p.m. Launch, February 26th.

KENYA CASTLE, passenger liner; built by Harland and Wolff, Ltd. for the Union Castle Mail Steamship Company, Ltd.; length between perpendiculars 540ft, breadth moulded 35ft 6in, 17,041 tons gross; four complete decks, ten watertight compartments, five cargo holds, 530 passengers in one class; two sets of Parson's triple expansion, condensing, double-reduction geared turbines, three Babcock and Wilcox oil-fired watertube boilers supply steam at 450 lb per square inch and 750 deg. Fah.; two 750-kW turbo-generators and three 450-kW diesel-driven generators. Trial: February 27th.